A STUDY OF URBAN RAIL TRANSIT DEVELOPMENT EFFECTS IN BANGKOK METROPOLITAN REGION

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A STUDY OF URBAN RAIL TRANSIT DEVELOPMENT EFFECTS IN BANGKOK METROPOLITAN REGION

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ABSTRACT

Bangkok Metropolitan Region (BMR), also known as Greater Bangkok is the urban conglomeration of Bangkok, Thailand, consists of a large core so-called Bangkok Metropolitan Area (BMA) and the five vicinities of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon. In the early period, most people settled along the Chao Phraya River and the canals. Waterway served as the main mode of transportation for Bangkoknians' commuting. By the mid-19th century, the commuting system was changed from water transport to land transport and had emphasized plans of transportation infrastructures such as bridge and road network. There have seen significant urban shifts in land use and travel behaviors. Specifically, this gradually converted Bangkok into a car dependency city and made the city spread outwards. Physically, employment locations are largely concentrated in the inner core. Such urban structure unavoidably generates huge amount of travel demand which are mostly made by long distance trips by private vehicles. The transportation in Bangkok is presently based on road and expressway network. The reason is that travel on private car is far superior to travel on crowded bus running in heavily congested traffic. The present 404 bus routes are still not enough to accommodate the travel demand especially from/to suburban areas. Then, the urban rail transit via the Mass Rapid Transit Master Plan has been introduced to alleviate the traffic issues and mainly serves people between suburban to the central part of Bangkok. According to that plan, the based-rail rapid transit development, in particular urban rail transit, has been promoted as a top priority project in 20 years plan. That urban rail transit brings large impacts to the relative attractiveness of the locations near the urban rail transit networks is well recognized in many developed countries, however, in a city being young in urban rail transit experience like the BMR is not gaining more attention. This research attempts to understand the effects of urban rail transit network expansions on land development in Bangkok Metropolitan Region, Thailand in viewpoints of land use change, land value uplift and residential location decision. The benefits due to rail transit development also impact on the areas which are announced in the top priority project in 20 years plan extension.

For the study of land use change due to the urban rail transit development, the conversions of land within 5 kilometer along the existing and under construction urban rail transit corridors between 2004 and 2010 were intended to investigate. Satellite images were used to track the conversions of land parcel at the same address but different years. To identify the conversions, each land parcel was aggregated into four categories: undeveloped land (agricultural land or no buildings), residential land (detached house, semi-detached house, attached house, and row house), high-rise residential land (condominium and apartment) and non-residential land (commercial and industrial). Specifically, undeveloped land category was selected as an initial state of land use in the year 2004. A traditional discrete choice model, namely multinomial logit model, was applied to investigate whether urban rail transit investment alter the urban form.

Next, examining of the extent of the influence of urban rail transit investments in the context of land price was captured. Land price data obtained from the Treasury Department, Thailand, which was published in the year 2008, was employed to capture the capitalization effects. A global regression framework was applied to determine the premium value of land based on its attributes. The global regression assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, the variations of the influences on the land value were revealed by classifying data into different groups of land use such as residential and non-residential and incorporating spatial heterogeneity. The spatial statistical test was based on the geographically weighted regression model (GWR) that allows estimating a model at each observation point. Understanding those impacts is necessary in order to allow the public agencies to tax the direct beneficiaries of their investments in the affected districts in advance so as to finance infrastructure projects.

Then, whether the effects of urban rail transit development associated with residential location decision was presented. In fact, there are many factors might contribute to differences in household residential location decision. However, many previous literatures indicated that transportation accessibility plays the important role in residential decision making. As known, the urban rail transit development provides a high level of access to other activities for households such as access to work, shopping, etc. The hypothesis that is, improving in transportation accessibility was reflected as one of the dominant factors for the residential location decision. Traditional discrete choice model, namely, multinomial logit (ML) and nested logit (NL) model together with an application of discrete choice model for a ranking of alternatives, i.e., rank-ordered logit (ROL) and ranked-ordered nested logit (RONL) model were applied. The mainly data used for this examining was obtained from a stated preference survey in Bangkok Metropolitan Region, Thailand incorporating with other variables such as local transportation accessibility, work and non-work accessibility, house affordability, neighborhood amenity and land attribute together with household characteristics.

The results from the models vary with socioeconomic and locational attributes such as local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute confirm that the urban rail transit development influences on the land development in terms of land use change, land value and residential location choice. The urban rail transit development resulted in higher land price and an invisible increase of land development among residential, high-rise residential and non-residential property as well as a higher agglomeration of population and household near the urban rail transit corridors. For instance, BTS Skytrain and MRT Blue Line network connected to the central business district (CBD) of Bangkok Metropolitan Region generated high-rise residential developments (e.g. luxury condominium and apartment) with higher values near their stations, while residential development was greatly found that in the area along the Airport Rail Link corridor with the lower value than those development in adjacent area of BTS Skytrain and MRT Blue Line corridor. Further, those urban rail transit lines induce the conversion urban from to non-residential properties (e.g. office building, shop store, etc.) with higher bid-rent, but this effect was not found within 3 kilometer of the Airport Rail Link. Moreover, the estimated premium for urban rail transit accessibility is approximately 15 percent for residential land and non-residential land price along the BTS Skytrain as well as 10 percent for residential land and non-residential land price along the MRT Blue Line. However, the capitalization effects of proximity to Airport Rail Link stations found that the beneficial effects will worth less than 4 percent to residential land parcels and 2.5 percent to non-residential land parcels along the Airport Rail Link corridor. Besides, the residential location choice model indicated that the effect of the accessibility to BTS Skytrain stations has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Purple Line and MRT Blue Line stations, i.e., households prefer living near the BTS Skytrain stations, followed by MRT Purple Line and MRT Blue Line stations but less likely to live near the Airport Rail Link and SRT Red Line corridor. Besides, among urban rail transit users, they prefer to live close to the stations of BTS Skytrain, followed by the areas near the stations of MRT Blue Line due to the fact that areas can access the station easily with various feeder modes. When controlling for neighborhood attributes, low income households are more likely to live at locations which are close to the station of MRT Blue Line but high income households prefer to live close to the station of BTS Skytrain as middle income households. Notably, low income households are less likely to reside along the adjacent area of the SRT Red Line.

In accordance with the explanations, it can be notable that land development is a sequential process as a result of urban rail transit development. After BTS Skytrain and MRT Blue Line started their service, land along the corridors tended to be converted to residential uses uses where households were more likely to reside that is the reason for the land value uplift due to the extremely competition among the sites. On the other hand, households are less likely to prefer living in this zone along the Airport Rail Link corridor, however, the results also found in the same direction but lower value than BTS Skytrain and MRT Blue Line. This is considered as benefit brought by the urban rail transit development.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Many cities in developing counties are suffering many serious urban problems in particular population, urbanization and motorization which are the major underlying causes of several intractable problems such as traffic congestion, overloaded public transport systems, social inequity, contaminated or depleted water supplies, air pollution and other forms of environmental degradation. However, the traffic congestion is most apparent in megacities especially in developing countries, those with over 10 million inhabitants. In addition, gridlocked roads are getting worse with traffic up as the average speed in major cities in developing countries such as Bangkok and Manila drop to just 10 kilometers per hour, in contrast to developed countries such as Singapore and Hong Kong are higher than 20 kilometers per hour (United Nations, 1993). The World Bank (2002) emphasizes the problem of congested streets in developing countries and suggested that it is likely to worsen if most developing countries have about 100 cars per 1,000 persons compared with over 400 cars per persons in developed countries (Gakenheimer, 1999). Besides, the percentage of modal share in developing countries is lower than developed countries (Wright and Fulton, 2005). For example, private modal share was 53% while the public modal share 44% in 2005 in Bangkok. The reason is that travel on private car is far superior to travel on crowed bus running in heavily congested traffic. Solutions to these are the policies that have goals to improve accessibility, safety, and urban environment while develop and maintain a wealthy and healthy urban economy, offer a higher quality of life and transport opportunities for all community sectors. Therefore, a new paradigm shift in transport investments and urban development policies to make the cities more sustainable and economically viable has been implemented especially in rail-based transit systems (e.g. subway, light rail, commuter rail). Benefitting from the priority given to its rail transit system, Tokyo suffered less from road congestion (Hayashi, 2010).

That transportation and land use have closed relationship, i.e., transportation affects land use and land use affects transportation, has been recognized but less well understood. Over past decades, many studies have been increased concern in this interdependency and substantial attempts have been made to empirically investigate the connection among those impacts can be evaluated and discussed from various perspectives such as land use change, property values, land use accessibility, transportation costs, residential location decision, house affordability, traffic accidents, energy consumption, and pollution emissions by planners, economists, engineers, and geographer. The historic evolution of urban form, from dense, monocentric cities to urban sprawl, follows new transportation technologies particularly the private automobile (Muller, 2004). Over the last sixty years, low-density, automobile-oriented sprawl has become the dominant metropolitan growth pattern. From 1970 to 2000, the percentage of the population living in the inner city decreases by 8% in U.S. (Handy, 2005). From 1987 to 2000, population of the inner area has declined, but the outer area increased in Bangkok. The estimation suggests that transportation infrastructure investment in road network has driven this urban population decrease. The inner area population density decreased from 15.27 to 11.09 thousand/sq.km. (3.25 to 2.36 million people) while the outer increased from 0.77 to 1.28 thousand/sq.km. (0.67 to 1.12 million people) (Vichiensan, 2008). The results of empirical previous studies indicated that transportation and urban land use is closely inter-linked. In general, the transportation investments bring a large benefit to the accessibility of the population to employment, retail and recreation activities that accessibility was reported to be of varying importance for different types of land uses. More specifically, locations with high accessibility tend to be converted faster than other areas such as residential areas. It is, therefore, improvement in accessibility invoke a more dispersed spatial organization of land developments.

The key to understand these effects are the concept of accessibility which is a general term used to characterize the ease of reaching opportunities or activities. An important function of transportation system in particular urban rail transit system is to provide for people accessibility to residences; places for employment, recreation, shopping and so on; and for public goods and services, accessibility to points of production and distribution. As stated above, it can refer that the structure and capacity of rail transit networks affect the level of accessibility. Then, locations in the vicinity of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become the attractiveness locations for commercial developments and residential developments which lead to increased land values as competition for the sites rises.

Although, that urban rail transit brings large impact to the relative attractiveness of the locations near the railway networks is well recognized in many developed countries, however, in a city being young in urban railway experience is not gaining more attention. This research attempts to understand the effects of urban rail transit network expansions on land development. Bangkok Metropolitan Region (BMR), Thailand, is selected as a representative capital city of developing countries. According to the Mass Rapid Transit Master Plan in Bangkok Metropolitan Region, the based-rail rapid transit development has been promoted as a top priority project in 20 years plan. The benefit due to rail transit development also impact on the areas which is announced future extension. The information from the studies is able to describe which transportation principles and strategies to use and how to incorporate them into land use planning process. For instance, the design of transportation facilities such as transit stations, feeder system, roads, driveway access points and sidewalks has major impact on the location characteristics. Perhaps, the idea will help the city planners to create similar choice environments in other areas. Also, the results can form the basis formulation of value capture policies to tax the direct beneficiaries in the affected districts in advance so as to finance the urban rail transit infrastructure projects, in particular the more than 10 transit lines that are planned for construction in the future.

1.2 Statement of Problems

Bangkok Metropolitan Region (BMR), also known as Greater Bangkok is the urban conglomeration of Bangkok, Thailand, consists of a large core so-called Bangkok Metropolitan Area (BMA) and the five vicinities of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon. In the early period, most people settled along the Chao Phraya River and the canals. Waterway served as the main mode of transportation for Bangkoknians' commuting. By the mid-19th century, the commuting system was changed from water transport to land transport and had emphasized plans of transportation infrastructures such as bridge and road network since 1960. There have seen significant urban shifts in land use and travel behaviors. Specifically, this gradually converted Bangkok into a car dependency city and made the city spread outwards (Rujopakarn, 2003). According to that plans, Bangkok has undergone rapid population, urbanization and motorization. The population increased from 3.3 million in 1960 to 14.6 million in 2010 and the BMR produced a GDP of about 4.77 trillion baht which accounts for 44.1 percent of country (National Statistical Office, NSO). Furthermore, the per capita of the people in the BMR continue to be higher than those of other regions. For example, the Northeastern region has the lowest, though this region corresponds to about one-third of Thailand and the total population of its 19 provinces in 2000 was 20.1 million, equivalent to approximately 34 percent of Thailand's total population but the annual per capita income in the BMR was ten times higher than in the northeastern region in 2010. Such situation has made it possible for many individuals and households to purchase new house in suburban areas as well as new vehicles. Physically, employment locations are largely concentrated in the inner core. Such urban structure unavoidably generates huge amount of travel demand which are mostly made by long distance trips by private vehicles. The transportation in Bangkok is presently based on road and expressway network. The reason is that travel on private car is far superior to travel on crowded bus running in heavily congested traffic. The present 404 bus routes are still not enough to accommodate the travel demand especially from/to suburban areas. Then, the urban rail transit has been introduced to alleviate the traffic issues and mainly serves people between suburban to the central part of Bangkok.

The BMR is still young to its urban rail transit history, i.e., three lines including BTS Skytrain, MRT Blue line, and Airport Rail Link, are now full operating. An important function of any urban rail transit system is to provide for people accessibility to residences; places for employment, recreation, shopping and so on; and for public goods and services, accessibility to points of production and distribution. Consequently, it can note that the structure and capacity of rail transit networks affect the level of accessibility. Then, the area near improved rail transit station facilities has become the attractiveness areas for commercial developments and residential developments. For example, the urban rail transit has large influence on its surrounding area, especially around the stations. After the BTS skytrain in Bangkok has opened, many buildings (e.g. office buildings, hotels, condominium, etc.) have been renovated and constructed by developers and land price along the corridor has remarkably increased (Vichiensan *et al.*, 2011). It was claimed that the premium of transit accessibility adding to the property value is approximately $10 per square meter for every meter closer to the station (Chalermpong, 2007). More recently, Bangkok Metropolitan Region in Thailand has developed a long-range transportation master plan and placed the top priority to urban rail transit investments. Thus, this plan has encompassed a wide range of elements of urban structure and transportation. Those benefits due to rail transit development also impact on the areas which is announced future extension. Such benefits make integrated models of land use and transportation very relevant for prediction of future urban structures. Therefore, the information from this research is very important factors for planning process of integrating the development impacts into the policies or master plan of transportation development.

1.3 Research Purpose

According to the Mass Rapid Transit Master Plan in Bangkok Metropolitan Region, the based-rail rapid transit development has been promoted as a top priority project in 20 years plan. That development will bring large effects to the relative attractiveness of the locations near the railway networks, certainly. However, lacking an idea to evaluate land development effects of urban rail transit investment is the characteristics of a city being young in urban railway experience like Bangkok Metropolitan Region. Thus, this research attempts to understand the effects of urban rail transit network expansions on land development in Bangkok Metropolitan Region in order to planning and evaluation of transport project in viewpoint of benefits from being located near the improved stations or corridors. The information from this research will be important for the policy implication.

In order to identify the extent of the effect consideration in planning and evaluation due to the urban rail transit development on land development, there are three principal ways to be performed as follows;

- To determine the extent of the influence of urban rail transit system on the conversions of land near improved urban rail transit facilities.

- To investigate how the urban rail transit investment has effects on the land price change.

- To examine whether the effects of urban rail transit development on the residential location decision are closely related

1.4 Organization of Dissertation

This dissertation contains a total of seven chapters. This chapter provides the introduction, the problems which are to be mainly focused, the main purpose and specific objectives. The remaining chapters and their brief contents are organized as follows:

Chapter 2 reviews previous researches and literatures relating to a research problem. Furthermore, the previous studies and existing literatures in Bangkok Metropolitan Region are also summarized. The review of literature, in addition, aims at providing detailed account of earlier studies in order to identify the gap that exists in the literature, which this research attempted to fill.

Chapter 3 explains the background and characteristics of Bangkok Metropolitan Region from the past until now. Furthermore, it describes the urban land patterns and transportation policies.

Chapter 4 intends to examine the effects of urban rail transit both existing network and under construction in three principal ways. One of them was presented in this chapter which aims to track and observe the conversions within the areas along the existing and under construction urban rail transit corridors in Bangkok Metropolitan Region, Thailand between the year 2004 and 2010. Then, investigate whether or not land use change occurred and how. In order to tracking and observing the land conversion, satellite images covering the areas within 5 kilometers radius centered from the corridors were used by comparing land parcels in a certain place but at different years. To identify the conversions, each land parcel is aggregated into four categories: undeveloped land (agricultural land or no buildings), residential land (detached house, semi-detached house, attached house, and row house), high-rise residential land (condominium and apartment) and non-residential land (commercial and industrial). These categories simplify the conversion analysis. An application of discrete choice model, namely multinomial logit model, is applied to investigate whether urban rail transit investment alter the urban form. This will be valuable information in which types of land use conversions are most profitable with respect to distance from the stations and other variables including local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute.

Chapter 5 has the ultimate goal of examining the extent of the influence of rail transit investment in the context of land price. Specifically, this study determines the spatial variation of the relationship between land price, and its attributes and accessibility to transit service. A global regression framework is applied to determine the value of land based on its attributes. The global regression assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, the variations of the influences on the land value are revealed by classifying data into different groups of land use such as residential and non-residential and incorporating spatial heterogeneity. The spatial statistical test is based on the geographically weighted regression model (GWR) that allows estimating a model at each observation point. The global regression model showed a significant correlation between land prices and its attributes and accessibility to transit service. However, the GWR model provided a better fit and revealed that rail transit has a positive impact on land price in some areas but negative in others.

Chapter 6 presents the final objectives of this study that is whether the effects of urban rail transit development associated with residential location decision. In fact, there are many factors might contribute to differences in household residential location decision. However, many previous literatures indicated that transportation accessibility plays the important role in residential decision making. As known, the urban rail transit development provides a high level of access to other activities for households such as access to work, shopping, etc. The hypothesis is improving in transportation accessibility will be reflected as the dominant factor for the residential location decision, i.e., exploring the role of urban rail transit lines in determining residential location decision. Traditional discrete choice models, namely multinomial logit (ML) and nested logit model (NL) were used to estimate in many substantial studies, however, an application of discrete choice model for a ranking of alternatives, i.e., rank-ordered logit (ROL) and ranked-ordered nested logit (RONL) model were also applied to determine in this chapter. The mainly data used for this examining was obtained from a stated preference survey in Bangkok Metropolitan Region, Thailand incorporating with other variables such as local transportation accessibility, work and non-work accessibility, house affordability, neighborhood amenity and land attribute. Furthermore, another important point of this chapter is to examine the variations in sensitivity across the households to those attributes.

Chapter 7 concludes the findings obtained from the examination in chapter 4 to chapter 6. Next, the limitations in this study were summarized. Further, the study contribution and implication are explained. Finally, the future prospects for further research regarding this filed are discussed.

The research flow diagram was developed to attain the research goal as illustrated in Figure 1 - 1.

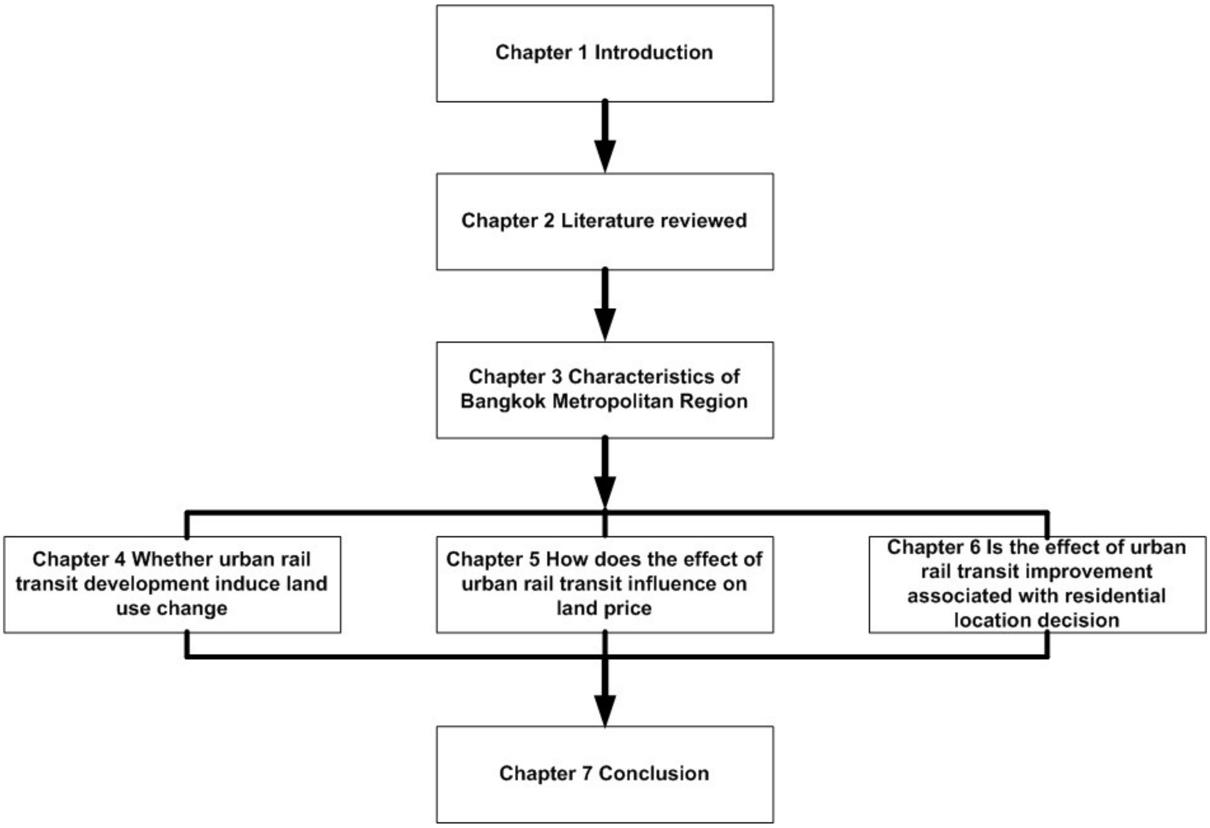

Figure 1 - 1 Flow Diagram

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CHAPTER 2

LITERATURE REVIEW

In this chapter, previous researches and literatures relating to a research problem were reviewed. The review of literature, in addition, aims at providing detailed account of earlier studies in order to identify the gap that exists in the literature, which this research attempts to fill. As stated in Chapter 1, the main purpose of this dissertation is to provide the basic framework and strategies to integrating the impacts of transportation system development especially urban rail transit system into the transportation and urban planning policy. There are many of literatures that examine the interactions between land use or urban spatial structure and transportation investments. However, this study focuses on the transportation investment, in particular urban rail transit investment and examines its effects in three principal ways: land use change, land value and residential location choice. This is because above three components play an importance role in urban development and widely impacts over areas in Bangkok Metropolitan Region.

2.1 Land Use and Transportation Interaction

A theory on the interaction between land use development and transportation, i.e., transportation affects land use and land use affects transportation, is recognized but less well understood. The traditional land use and transport modeling approach represents response of land use policies to travel patterns, but response of transportation policies is, however, not well represented. In other word, change in transportation options is assumed to have no response to change in land use or land development especially in city being young experience in modern transportation innovations such as urban rail transit.

Land use development also called urban from, urban design, urban society, build environment, community design, spatial structure, and urban geography is the adaption of land cover in order to serve the human needs and activities which are mainly concerned with residence, production, and consumption. Major land use categories for urban space are residential, commercial, institutional, industrial, undeveloped, and transportation facilities. Transportation system plays the major role of the linkage among those activities. It offers the opportunities for movements of people and goods between each location in urban structure. That is, transportation planning decisions influence land use directly, by affecting the amount of land used for transport facilities, and indirectly, by affecting the urban form. For instance, expanding highways increases pavement area, and encourages more dispersed, while walking, cycling and public transit improvements encourage compact. In turn, the urban from can have diverse economic, social and environmental impacts (Rodrigue *et al.*, 2013).

More than a half century, substantial attempts have been made to empirically investigate the connection among those impacts can be evaluated and discussed from various perspectives such as property values, land use change, land use accessibility, transportation costs, residential location decision, house affordability, traffic accidents, energy consumption, and pollution emissions by planners, economists, engineers, and geographer. The historic evolution of urban form, from dense, monocentric cities to urban sprawl, follows new transportation technologies particularly the private automobile (Muller, 2004). Recent estimates suggest that one new highway passing through the inner city reduced that city's population by 17% between 1950 and 1990 (Baum-Snow, 2007). Throughout the latter of the 19th century and into the 20th, a new series of technological innovations ranging to modern mass rapid transit have been introduced. Each succeeding wave of innovation has permitted an almost explosive expansion of the city. When most of these improvements were made, the country's urban population was growing rapidly through immigration as well as rural-urban migration (Knight, 1980). In China, Take Hui Longguan station in the scope of 2 km radius from the Hui Longguan station of the No.13 Line, the living space was mainly rural and townhouse sites, and the residential area only accounts for 4.1 percent of the total area in 1996. However, in 2003, this percentage increased to 39.3% and was 8.59 times as much as the percentage in 1996. Conversely, residential area is dramatically decreased in the inner core of city (Ma *et al.*, 2010). Moreover, the study also showed that the urban rail transit investment has less impact on a housing price in the city, but has a huge impact in the suburban area. Low density and a doughnut hole of population and employment density in city centers of U.S. increasingly characterize modern cities. Policies such as the Federal Highway Acts and the Standard Zoning Enabling Acts have drastically affected land use, expanding housing and employment into suburban areas. Instead of the Central Business District (CBD) containing and vast majority of a region's office floor-space, many new cluster of office building have sprung up in the suburban area (Pivo, 1990). In Munich, Kreibich (1978) analyzed suburbanization in the Munich Metropoiltan Area after the opening of the Munich S-Bahn system in 1972 and found increasing residential growth rates along the S-Bahn Lines fanning out into the Munich hinterland. Pharoah and Apel (1995) in their comparison of transport concepts in European cities observed that policies to promote public transport over car tend to have strong positive effects on the economic development of city centers, whereas the negative effects of car restraint policies frequently feared by local businessmen have in no case been confirmed by empirical evidence. They note, however, that the causal relationship may work in the opposite direction: that city centers are not attractive because they are accessible by car but that attractive city centers can afford to be less accessible by car. Zondag and Pieters (2005) was to analyze the influence of transport in residential location choices and the empirical findings were suggested that the role of accessibility is significant but small compared with the effect of other factors such as demographic, neighborhood amenities.

The results of empirical studies indicated that transportation and urban land use is closely inter-linked, i.e., transportation affects land use and land use affects transportation. In general, the transportation investments bring a large benefit to the accessibility of the population to employment, retail and recreation activities that accessibility was reported to be of varying importance for different types of land uses. More specifically, locations with high accessibility tend to be converted faster than other areas such as residential areas. It is, therefore, improvement inaccessibility invoke a more dispersed spatial organization of land uses. As previously stated, the main purpose of this dissertation is to provide the basic framework and strategies to integrating the impacts of transportation system development especially urban rail transit system into the transportation and urban planning policy. It is necessary to understand the effects of public investment in urban rail transit on land use change, land value and residential location choice due to the fact that these three components play an importance role in land development in Bangkok. Specifically, the increases in land values around the major transportation infrastructure projects generated by urban rail transit have been expected developers before the project completed, then, they invest in properties along the major transportation infrastructures because they could make a lot of money from others due to the fact that properties being located near the station provide the opportunities for get around easily. The most of investment in land is likely to develop to real estate for residential uses, e.g., single-family housing and multi-family housing. This benefit will be definitely reflected to the more than 10 transit lines that are planned for construction in the future. Understanding those impacts is necessary in order to allow the public agencies to tax the direct beneficiaries of their investments in the affected districts in advance so as to finance infrastructure projects.

Review of existing studies in land use change, land value as well as residential location decision effects of transportation investments, in particular urban rail transit development is summarized the research questions, hypotheses, plans, strategies and methods of investigation of issues related to the urban rail transit impacts in developed and developing countries.

2.2 Theoretical and Empirical Studies of Land Use Change

Many substantial attempts have been made to empirically investigate the connection between transportation investments and urban land development forms for more than 30 years. Bell (1974) and Knight (1980) are perhaps the well-known among earlier inquires of urban structure and land use pattern. Moreover, there is a numerical of studies that attempt to estimate the impacts of transportation investments on land use change. These studies are common and/or different in the model structure utilized, the types of properties, the significant determinants factor and the findings. Some of these studies are summarized as presented Table 2 - 1.

2.2.1 Land Use Change Model

Many previous studies in developed countries and a few in developing countries summarized and interpreted the association between land use and transportation development. Although lots of the existing models have been developed, there is no clearly superior approach. This is due to the requirements of model developers, modeling objectives, as well as the availability and reliability of data.

Some studies in the early work used the simply statistic data and compared in order to conclude the land use change impacts (Dueker and Bianco, 1988; Giuliano, 1989; Knight, 1980; Knight and Trygg, 1977). Some previous literatures have been tested with the most common functional forms, namely discrete choice model or so-called multinomial logit model (Cervero and Kang, 2011; Haider and Miller, 2000; Iacono and levinson, 2009; Meng and Zhang, 2011; Verburg *et al.*, 2004). Several studies attempted to capture the capitalization of transportation improvements using Markov analysis (Bell, 1974; Bell and Hinojosa, 1976; Levinson and Chen, 2005; Weng, 2002). Furthermore, advanced techniques in land use change studies have been applied to examine the data problem with spatial effect (Carrión-Flores *et al.*, 2009; Wang and Kockelman, 2006; Zhou and Kockelman, 2008; Zhou *et al.*, 2009).

Though the overall approach is similar in all hedonic studies, a number of different focuses were adopted by researchers, depending on the aspects of problem, research purposes and data available. For example, previous studies examined the changes of land use such as residential (Carrión-Flores *et al.*, 2009; Iacono and levinson, 2009; Verburg *et al.*, 2004; Wang and Kockelman, 2006), commercial (Landis *et al.*, 1995; Zhou and Kockelman, 2008), and industrial (Carrión-Flores *et al.*, 2009; Landis *et al.*, 1995; Verburg *et al.*, 2004) due to the impacts of different types of transportation infrastructure including rail transit (Dueker and Bianco, 1988; Huang, 1996; Hurst, 2011; Knight, 1980; Knight and Trygg, 1977; Landis *et al.*, 1995), bus rapid transit (Cervero and Kang, 2011), and highway infrastructure (Forkenbrock and Foster, 1990; Funderburg *et al.*, 2010; Giuliano, 2004).

2.2.2 Relationship between Urban Rail Transit Investment and Land Use Change

The earlier modern studies of the connection between rail transit system and land use were conducted by Knight and Trygg (1977) and (Knight, 1980). They observed the impact of Bay Area Rail Transit (BART) system on land use change using summary statistics and interviews to conclude that beneficial land use changes due to the Bay Area Rail Transit (BART) system. On the basis of available evidence, it was not clearly established a causal relationship between rail transit and changes in land use and development patterns. At best, such changes would seem to occur only in the presence of other favorable factors, such as supportive local land use policies and development incentives, availability of developable land and a good investment climate. Likewise, Dueker and Bianco (1988) examined the effects of light rail transit in the Portland Region and the statistical data provided evidence that light rail alone has not been sufficient to have an appreciable impact on development patterns and residential density, although there has been some positive effect of rail on single-family property values.

Table 2 - 1 Previous Studies in Land Use Change

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Dueker and Bianco (1988) Portland, USA	Statistical analysis	Land use maps	➢ Residential	➢ n/a	➢ Light rail alone has not been sufficient to have an appreciable impact on development patterns, residential density, although there has also been positive effect of rail on single-family property values
Landis *et al*. (1995) San Francisco, USA	Multinomial logit model	Land use maps	➢ Undeveloped ➢ Residential ➢ Commercial ➢ Public ➢ Industrial ➢ Transportation	➢ Distance to station ➢ Vacant land availability ➢ Station area dummy	➢ Although there has been a significant amount of land use change near BART stations since the system was first constructed, station proximity by itself did not seem to have a large effect on nearby land use patterns ➢ However, various statistical models were developed to separate the effect of station proximity from other factors that affect station area residential and commercial land use changes ➢ The closer a vacant site in Alameda County was to a BART station, the more likely it was to be developed in commercial or industrial but in Contra Costa County, vacant sites near BART station were less likely to be developed into commercial or industrial uses. Furthermore, in both counties, vacant sites near BART stations were less likely to be developed to residential uses. ➢ Residential sites near BART stations were far moiré likely t be redeveloped to commercial or industrial uses than more distance residential sites
Hardie and Parks (1997) A five-state region in the southeastern , USA	Multinomial logit model	Land use maps	➢ Forest ➢ Farmland ➢ Urban land	➢ Population density ➢ Per capita income ➢ Owner' age	➢ Increases in population density shift land away from farm and forest use ➢ Per capita income increases also are consistent with a shift of land into urban/other uses ➢ Land will shift from farmland into forest and other nonfarm uses when the age of the representative landowner is increased
Lo and Yang (2002) Atlanta, USA	Multiple correlation analysis	Land use maps	➢ Developed ➢ Undeveloped	➢ Population density ➢ Income ➢ Urban center proximity ➢ Highway proximity ➢ Node point proximity ➢ Shopping mall proximity	➢ Population and site location characteristics were important in determining the land-use or land-cover changes ➢ Per capita income has shown a strong relationship with cropland

Table 2 - 1 Previous Studies in Land Use Change (cont.)

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Verburg *et al.* (2004)	Multinomial logit model	Land use maps (Grid cells 25m x 25m)	➢ Grassland ➢ Arable ➢ Land ➢ Greenhouses ➢ Other agriculture ➢ Residential areas ➢ Industrial/commercial ➢ Forest/nature ➢ Recreational ➢ Airports ➢ Water	➢ Distance to railway station ➢ Travel time to railway station ➢ Distance to airport ➢ Travel time to airport ➢ Distance to motorway ➢ Travel time to highway entrance ➢ Average distance to nearest 100000 jobs ➢ Average travel time to nearest 100000 jobs ➢ Average distance to nearest 500000 jobs ➢ Average travel time to nearest 500000 jobs ➢ Distance to coast or main river ➢ Area with high noise	➢ Accessibility is important for all land use changes ➢ The closer the distance and shorter the travel time to city, town ,job opportunities and road and rail infrastructure, the greater the development ➢ New developments would avoid noisy locations that have higher levels of noise than others ➢ Almost 14% of all new residential areas were constructed within the growth centers ➢ Also, the growth centers were important for the allocation of new commercial and industrial compound ➢ For commercial and industrial land, the influence of the proximity of a highway was a main determining factor ➢ Not only was the distance or travel time to motorway intersection important, but also the location in the immediate neighborhood of the motorway: 40% of all new industrial and commercial areas were within 750 meter if a motorway but only 15% was not developed into industrial and commercial land ➢ New recreation areas is created near to forest/nature areas that also have a recreational function
Carrión-Flores and Irwin (2004) Ohio, USA	Probit model	Land use maps	➢ Developed ➢ Undeveloped	➢ Distance to Cleveland ➢ Distance to town ➢ Population density ➢ Residential area ➢ Commercial area ➢ Agriculture area ➢ Population	➢ The parcels located within approximately 14 miles of the outer boundary of the Cleveland urbanized area, the probability of conversion decreases at a decreasing rate with distance from Cleveland. However, for parcels located beyond this distance, the probability of conversion increases with distance from the urbanized boundary. The marginal effects which can be interpreted as the change in probability of conversion given a 1 km increase in distance, range from -1.3 for parcels located within a mile of urbanized boundary to 1.4 for parcels located the furthest away ➢ Population density is found to convey a negative effect, suggesting that new development is less likely to locate in densely developed areas ➢ Although surrounding agricultural land is not found to be significant relative to surrounding industrial land, the proportions of neighboring residential and commercial land confer a positive and significant effect

Table 2 - 1 Previous Studies in Land Use Change (cont.)

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Wang and Kockelman (2006) Austin Texas, USA	Mixed logit model recognizing temporal and spatial effects	Satellite image (Grid cells 30m x 30m)	➢ Undeveloped ➢ Residential ➢ Commercial/industrial/ transportation	➢ Distance to the nearest highway ➢ Distance to CBD ➢ No. of population ➢ Residential area ➢ Commercial/industrial/transportation area	➢ Neighboring population density reduce the likelihood of such transitions ➢ Higher population density may imply higher land price ➢ Development happens sooner in neighborhoods that are less populated but more developed ➢ Distance to the nearest highway increase, the probability of development falls ➢ Development is more likely to emerge away from the CBD, where land development restrictions are likely to be fewer, land value lower and construction costs lower
Zhou and Kockelman (2008) Austin Texas, USA	Multinomial logit model of spatial relationships	Orthophoto (Grid cells 40m x 40m)	➢ Undeveloped ➢ Residential ➢ Commercial ➢ Office ➢ Industrial ➢ Civic ➢ other	➢ Size ➢ Area ratio ➢ Slope ➢ Transit access ➢ Distance to CBD ➢ Distance to highway	➢ Residential development is less likely in neighborhood better served by transit. However, transit stops are cluster in the most developed areas of the City where new land development is rare and non-residential uses are relatively common ➢ Residential and office land uses are more likely to appear in undeveloped parcels near the city fringe ➢ Residential, commercial and office uses are likely to emerge near highways, taking advantage of transportation access ➢ Residential and commercial uses favor neighborhoods with less diverse land uses ➢ Clustering of like land uses is also found in the estimates of surrounding land use intensity
Zeng *et al.* (2008) Yongding County, China	Autologistic regression	Land use maps	➢ Arable land ➢ Woodland	➢ Distance to nearest town ➢ Distance to nearest river ➢ Distance to nearest major road ➢ Population density ➢ Elevation ➢ Slop ➢ Aspect ➢ Curvature	➢ Elevation, slope, aspect and curvature are three variables that are thought to have a significant role in explaining the presence of arable land ➢ Elevation, slope ,aspect, curvature and population density can explain relationship between the spatial pattern of woodland and drivers both classic logistic regression and autologistic regression models

Table 2 - 1 Previous Studies in Land Use Change (cont.)

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Carrión-Flores *et al.* (2009) Medina County, Ohio	Spatial multinomial logit model	Land use maps	➢ Undeveloped ➢ developed	➢ Population density ➢ Land size ➢ Distance to Cleveland	➢ A parcel size increase, the relative probability of commercial and agricultural land uses is higher than industrial land use. On the other hand, the relative probability is lower between residential and industrial land users as the parcel size increases ➢ Industrial land uses become less attractive as distance to Cleveland increases ➢ The relative probability of commercial, residential and agricultural land uses is higher than for industrial land use as distance to nearest town decreases ➢ Population density is found to increase the relatively probability of agricultural, commercial and residential land uses relative to industrial ➢ House density lowers the relative probability between residential and industrial land uses
Iacono and levinson (2009) Twin Cities, Minnesota	Multinomial logit mode	Land use maps	➢ Airport ➢ Commercial ➢ Highway ➢ Industrial ➢ Parks ➢ Public ➢ Railroad ➢ Residential ➢ Vacant ➢ Water	➢ Neighborhood land use ➢ Road dummy ➢ Accessibility to highway network ➢ Employment accessibility	➢ The set of neighbor variables also increases the likelihood of transition ➢ Having highway networks in neighboring cells appear to increase the likelihood of transition to commercial and industrial land uses while having no real effect on transition to vacant land and having negative influence on the likelihood of transition to residential use ➢ High levels of accessibility to job are associated with a higher likelihood of transition to commercial land use , to a lesser extent, industrial land use ➢ The effect of employment accessibility on transition to residential land use is slight and negative in the case of transition to vacant land ➢ Residential land in relatively accessible locations is more valuable than vacant land

Table 2 - 1 Previous Studies in Land Use Change (cont.)

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Funderburg *et al.* (2010) Santa Clara County	Quasi-experimental	Land use maps	➢ Developed ➢ Undeveloped	➢ Total population ➢ Total employment ➢ Total income ➢ % housing stock before 1960 ➢ % housing stock before 1940 ➢ Median age of housing stock ➢ Freeway within 2 miles	➢ New Orange County jobs occurred within a typical census tract in the County's formerly exurban region after gaining highway access when compared to no build counterfactuals ➢ No significant effects on population or employment growth that can be attributed to the new highway investments near the urban center of Santa Clara County ➢ Also find some evidence in Merced County to suggest that highway infrastructure induces changes in land use , in particle employment
Cervero and Kang (2011) South Korea	Multilevel logit	Land use maps	➢ Residential (single-family housing and multi-family housing)	➢ Distance to bus stop ➢ Distance to CBD ➢ Distance to Freeway ramp ➢ Distance to subway station ➢ Distance to Han river ➢ Job accessibility within 30 min by car ➢ Population density ➢ Employment density ➢ Age structure ➢ Park ratio ➢ Road area ratio	➢ For all single-family parcels within 0.5 kilometer of a bus stop were more likely to convert to more intensive uses ➢ The higher-end conversion to condominium and mixed use buildings were less likely to occur within the immediate vicinity if a bus stop ➢ Beyond a buffer distance of 100 meters to a bus stop, single-family conversions were more likely to occur ➢ Distance to arterial roads had the strongest influence on land use conversions but the likelihood of switching to multi-family and mixed uses fell with distance to arterial roads ➢ Distance to city hall and subway station were statistically associated with condominiums and mixed uses conversions ➢ Higher assessed land values of a neighborhood significantly increased the odds of converting single-family residences I the higher end uses: condominiums and mixed uses ➢ Less appealing in higher valued core areas of the city were conversions to multi-family housing
Meng and Zhang (2011) Georgia, USA	Discrete choice based on Markov transition	Land use maps	➢ Crop ➢ Pasture ➢ Forest ➢ CRP ➢ developed	➢ Property taxes ➢ Population density ➢ Land quality	➢ Lands converted from forest to CRP are less likely to happen and lands converted from crop to forest are more likely to happen ➢ CRP lands most likely came from croplands ➢ High quality land is likely to be converted, in a declining order, to croplands, developed use and pasture, and least likely to be converted to forests from any initial use

Table 2 - 1 Previous Studies in Land Use Change (cont.)

Study	Model Structure	Land Use Data	Type of Property	Accessibility/Determinants	Main Findings
Ferdous and Bhat (2013) San Francisco, USA	Spatial logit model	Land use maps	➢ Undeveloped land ➢ Low intensity developed land ➢ Medium intensity developed land ➢ High intensity developed land	➢ Distance to a park ≤ 2 miles ➢ Distance to a lake ≤ 5 miles ➢ Distance to school ≤ 2 miles ➢ Distance to the downtown area ≤ 9 miles ➢ Distance to IH-35 ≤ 9 miles ➢ Distance to a public airfield ≤ 1 miles ➢ Parcel is located in Austin city (1/0)	➢ Parcels located within close proximity of a park (distance ≤ 2 miles) and/or a lake (distance to a lake ≤ 5 miles distance) are perceived by land owners as providing high returns to development relative to parcels located farther away from such natural amenities ➢ Proximity to a school also affects land development intensity level ➢ A lower LUDR perception for parcels located in close proximity (≤ 9 miles) of the Austin CBD relative to those located farther away (> 9 miles) ➢ Proximity and access to major roadways generally has a positive impact on development intensity (even if certain kinds of developments such as industrial facilities are precluded by zoning regulations to be located very close to major roadways)

Recent, Landis *et al.* (1995) explored the five urban rail transit system in California (BART, CalTrain, Sacramento light rail, the San Diego Trolley and Santa Clara light rail) and land use connection. Although there has been a significant amount of land use change near BART stations since the system was first constructed, station proximity by itself did not seem to have a large effect on nearby land use patterns. However, the effects of station seem affect station area residential and/or commercial land use changes. The changes of land uses emerge varying on each station site. For example, the closer a vacant site in Alameda County was to a BART station, the more likely it was to be developed in commercial or industrial use, but it was less likely to convert in Contra Costa County. However, in both counties, vacant sites near BART station were less likely to be developed to residential use, in particular far less likely in case of Contra Costa County. Additionally, residential sites near BART stations were far more likely to be redeveloped to commercial or industrial uses than more distance residential sites. Verburg *et al.* (2004) analyzed the changes of land use in Netherlands and found that accessibility is important for land use changes studied, i.e., the closer the distance and shorter travel time to rail infrastructure, the greater the development. More recently, Zhou and Kockelman (2008) investigated neighborhood impacts on land use change and the results suggested that residential development is less likely in neighborhoods better served by transit. However, transit stops were clustered in the mode developed areas of the City, where new land development is rare and non-residential uses were relatively common. Thus this transit variable may be picking up many effects of centrality and commercial development, rather than nothing purely access consideration. Cervero and Kang (2011) attempted to observe the impacts on land use changes in Seoul, Korea and the results indicated that distance to subway stations were statistically associated with condominiums and mixed uses conversions, albeit in no clearly discernible pattern.

2.2.3 Determinants of Land Use Change

2.2.3.1 Access and Accessibility

Access and accessibility refers to ease of reaching destinations with people in places that are highly accessible reaching many other activities. Most studies focused on work accessibility and non-work accessibility.

Work accessibility, in general, measures in various ways such as the nearest distance to the destinations (e.g. the CBD and subcenters) and gravity model of job accessibility. For example, Wilder (1985) indicated that commercial activities are strongly clustered in the CBD while clusters of new residential development are found in the areas far from one mile of the CBD but very few conversions are found at distance greater than four miles from the CBD. Carrión-Flores and Irwin (2004) indicated that parcels located within approximately 14 miles of the outer boundary of the Cleveland urbanized area, the probability of conversion decreases at a decreasing rate with distance from Cleveland, however, parcels located beyond this distance, the probability of conversion increases with distance from the urbanized boundary. Also, the probability of conversion increases as distance from the nearest town increases. Similarly, it was clear that new residential areas are preferably located with easy access to towns and cities (Verburg *et al.*, 2004). Iacono and levinson (2009) showed that high level of accessibility to job are associated with a higher likelihood of transition to commercial land use but slightly effect in the change of residential land use. In contrast, the result suggested that land development is more likely to emerge away from the CBD, where land development restrictions are likely to be fewer, land values lower and construction costs lower (Wang and Kockelman, 2006). Likewise, residential and office land uses are more likely to appear in undeveloped parcels near the city fringe (Zhou and Kockelman, 2008).

Non-work accessibility, in general, measures in the same way of work accessibility. The most destinations where there were focused including recreation, shopping center, and the scenery areas (e.g. coast, river, park, city hall, etc.). For example, Lo and Yang (2002) indicated that proximity to shopping mall has become important factors promoting the growth of edge cities in Atlanta. (Newburn *et al.*, 2006) indicated that the percentage of open space do not appear to significantly affect residential conversion. Cervero and Kang (2011) showed that distance to city hall is statistically associated with condominiums and mixed uses conversions, albeit no clear or discernible pattern but park density ratio are less easy to explain and likely reflect local idiosyncrasies of Seoul's commercial real estate market. Ferdous and Bhat (2013) indicated that parcels located within close proximity of a park (distance ≤ 2 miles) and/or a lake (distance to a lake ≤ 5 miles distance) are perceived by land owners as providing high returns to development relative to parcels located farther away from such natural amenities.

Finally, another accessibility variable, the local transportation accessibility, is also used to capture the changes in land uses as well. For example, the influence of the proximity of a highway was a main determining factors for commercial and industrial land uses (Verburg *et al.*, 2004). Likewise, Wang and Kockelman (2006) showed that distance to the nearest highway increases, the probability of development falls. In addition, residential, commercial and office land uses are likely to emerge near highway network (Zhou and Kockelman, 2008). Similarly, they found some evidence that highway infrastructure induces the changes in land use especially land uses for employment (Funderburg *et al.*, 2010). Cervero and Kang (2011) indicated that a buffer distance of 100 meter to a BRT bus stop, single-family conversions are more likely to occur while, distance to arterial road had the strongest influence on land use conversions: the likelihood of switching to multi-family and mixed uses fell with distance to arterial roads. Ferdous and Bhat (2013) indicated that proximity and access to major roadways generally has a positive impact on development intensity

2.2.3.2 Neighborhood Amenity

Neighborhood amenity, in general, refers to the median income and zonal density. Conflicting observations have been drawn about the effect of density, e.g. population density, household density and employment density, on land use changes.

For the median income, median income increases were consistent with a shift of land into urban and other uses (Hardie and Parks, 1997).

Among the zonal density variables, Hardie and Parks (1997) indicated that increases in population density shift land away from farm and forest use to urban/other uses. The result revealed that population density is important in determining the land use changes in Atlanta, Georgia (Lo and Yang, 2002). However, population density is found to convey a negative effect, suggesting that new development is less likely to locate in densely develop areas (Carrión-Flores and Irwin, 2004). Wang and Kockelman (2006) indicated that neighboring population densities reduce the likelihood of transitions, particularly for commercial, industrial, transportation land because higher population density may imply higher land prices. Newburn *et al.* (2006) indicated that the importance of zoning for residential conversion is high density due to it increases rents per acre associated with residential uses. Carrión-Flores *et al.* (2009) indicated that population density is found to increase the relatively probability of agricultural, commercial, and residential land uses relative to industrial land while house density tend to lower the relatively probability between residential and industrial land use.

2.2.3.3 Other Variables

Higher land value is associated with the greater likelihood of conversions from single-family housing to commercial use, commercial to mixed-use, and mixed to commercial use while lower land value is linked the conversion of single-family housing to condominiums and to mixed-use (Cervero and Kang, 2011).

2.3 Theoretical and Empirical Studies of Property Value

Early attempted, the hedonic pricing model was empirical summarized of the relationship between the prices and the characteristics of goods sold in differentiated product market by Griliches (1961) and Rosen (1974). Moreover, there is a numerical of studies that attempt to apply this method so as to studying capitalization of rail transit accessibility. These studies are common and/or different in the model structure utilized, the types of properties, the significant determinants factor and the findings. Some of these studies are summarized regarding to the examination in the developed and developing countries as presented Table 2 - 2 and Table 2 - 3.

2.3.1 Hedonic Pricing Model

The hedonic price studies analyzed the effects of transportation improvements on property values have been long and widely used to estimate economic values for the urban rail transit services availability that directly affect the prices. In the other word, it is most commonly applied to variations in property prices, i.e., housing prices, residential and commercial land values and office and industrial space rents, that reflect the value of locational and neighborhood attributes. The basic premise of the hedonic pricing method is that the price of a marketed good is related to its characteristics or the services it provides. For example, the price of a residence reflects the characteristics of that residence – size, age, quality, interior design, the distance to daily activities (e.g. workplace, school, shopping center, retail shop supermarket and so on). Therefore, this method is able to value the individual characteristics of a residence or other good by looking at how the price people are willing to pay for it changes when the characteristics change.

In Table 2 - 2 and Table 2 - 3, present the hedonic studies in developed and developing countries, respectively. Over past three decades, many researchers in developed countries have developed hedonic model to examine the value of transportation improvements especially transit accessibility. But there have been increasing number of hedonic studies in developing countries in recent years. This could be explained by many newly transit complemented in developing countries as well as improvements data management.

Some of above studies are common and/or different in the model structure utilized, the types of properties, the significant determinants factor and the findings as stated. As seen in the table, model structures of the studies of the relationship between property values and their characteristics have been examined in various technical. For example, many previous literatures have been tested with the most common functional forms, namely linear regression or so-called the ordinary least square (OLS) (Bajic, 1983; Du and Mulley, 2006; Farooq *et al.*, 2010; Haider and Miller, 2000; Kim and Zhang, 2005). Several studies attempted to capture the capitalization of transportation improvements using semi-log, log-linear, Box-Cox transformation, generalized least squares, fuzzy regression, heteroscedasticy regression and two-stage least (Bae *et al.*, 2003; Bollinger *et al.*, 1998; Duncan, 2011; Lewis, 2007; Lin and Hwang, 2004). Furthermore, advanced techniques in hedonic studies have been applied to examine the data problem with spatial effects, namely spatial dependency and spatial heterogeneity (Armstrong and Rodríguez, 2006; Gao and Asami, 2005).

Though the overall approach is similar in all hedonic studies, a number of different focuses were adopted by researchers, depending on the aspects of problem, research purposes and data available. Several proxies of property value have been adopted, including transaction prices (Diao and Ferreira Jr, 2010; Pan and Zhang, 2008; Yiu and Wong, 2005), rents (Bollinger *et al.*, 1998; Cervero and Landis, 1993; Farooq *et al.*, 2010), assessed values (Boehm, 1982; Hess and Almeida, 2007; Lewis-Workman and Brod, 1997; Lewis, 2007), and asking rents and prices (Ryan, 2005). Furthermore, the hedonic studies have been used to examine the impacts of different types of transportation infrastructures including light rail (Forrest *et al.*, 1996; Hess and Almeida, 2007; Ryan, 2005; Yan *et al.*, 2012), commuter rail (Armstrong and Rodríguez, 2006; Cervero and Duncan, 2004; Chau and Ng, 1998; Diao and Ferreira Jr, 2010), subway (Bae *et al.*, 2003; Bajic, 1983; Kim and Zhang, 2005; Lin and Hwang, 2004; Wei *et al.*, 2012), highway and tunnel (Ryan, 2005; ten Siethoff and Kockelman, 2002; Yiu and Wong, 2005) on the values of various kinds of properties such as residential and commercial land (Cervero and Duncan, 2004; Du and Mulley, 2006; Kim and Zhang, 2005; McDonald and McMillen, 1990), single-family housing (Armstrong and Rodríguez, 2006; Bajic, 1983; Diao and Ferreira Jr, 2010; Yan *et al.*, 2012), multi-family housing (Duncan, 2011), commercial properties (Bollinger *et al.*, 1998; Cervero and Landis, 1993; Farooq *et al.*, 2010) and industrial properties (Ryan, 2005).

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries

Study	Model Structure	Type of Property	Determinants	Main Findings
Bajic (1983) Toronto, Canada	Hedonic regression and New subway line (Liner)	Housing prices	➢ House selling price ➢ Usable outdoor space, floor area, no. of rooms, no. of garage places ➢ Commuting time using public transit ➢ Auto in vehicle time from house location to the intersection of Bay and King Streets in downtown	➢ Comparing between 1971 and 1978, the overall shift in the implicit prices in the Spadina corridor was not caused by the opening of the new subway line, for the same shift occurred in the rest of Metropolitan Toronto, where the impact of the subway would not have had any effect ➢ For the decrease in commuting time, the effect of the subway on the market value of an average house in the Spadina area as $2,237 ➢ Also, the direct saving in commuting costs have been capitalized into housing values
McDonald and McMillen (1990) Chicago	Hedonic regression and employment subcenters	Land value	➢ Distance to CBD ➢ Distance to Lake Michigan ➢ Distance to US Steel South Works ➢ Distance to Union Stockyards ➢ Located within 2 miles of Stockyards ➢ Distance to Pullman	➢ Land values are found to decline 16% per mile with distance to the CBD ➢ Decline 10% per mile with distance to Lake Michigan, and to be higher in tracts adjacent to Lake Michigan ➢ The effect of distance to Lake Michigan, higher than in tracts not adjacent to Lake Michigan ➢ The steel plant is located on Lake Michigan and has no impact on land values and the results for the stockyards indicate that land values were significantly lower within 2 miles of the stockyards ➢ The empirical tests confirm that the O'Hare Airport area has emerged as a significant employment subcenter
Cervero and Landis (1993) Washington, DC	Quasi-experimental analysis	Office rental rate	➢ Average net office absorption ➢ Average office vacancy rate ➢ Average annual new square feet of office space ➢ Average square footage of office development per land parcel ➢ Average percent of new regional office and commercial floor space	➢ Office projects located at or near transit stations enjoyed a slight office rent premium over their freeway-oriented competitors ➢ Office projects near rail stations tended to be slightly larger, and lease up somewhat more rapidly than office projects at the nonrail control sites ➢ Although rail transit service does generate some benefits for the owners of commercial properties near transit stations, such benefits tend to be quite small
Forrest *et al.* (1996) Manchester	Hedonic regression and impact of light rail system (box-cox transformation)	Property sales in 1990	➢ Age, area, type of housing, no. of parking, no central heating, no. of bedrooms ➢ Distance to CBD ➢ Distance to station	➢ Property price increases with distance from the CBD ➢ 13% premium for 4 bedrooms, a 16% premium for semi-detached, 10% discount for the absence of central heating ➢ No significance was found on the bathroom variables ➢ Farther away from station tends to lower property price

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Forrest *et al.* (1996) Manchester	Hedonic regression and impact of light rail system (box-cox transformation)	Property sales in 1990	➢ Age, area, type of housing, no. of parking, no central heating, no. of bedrooms ➢ Distance to CBD ➢ Distance to station	➢ Property price increases with distance from the CBD ➢ 13% premium for 4 bedrooms, a 16% premium for semi-detached, 10% discount for the absence of central heating ➢ No significance was found on the bathroom variables ➢ Farther away from station tends to lower property price
Lewis-Workman and Brod (1997) San Francisco Queen, New York Portland, Oregon	Hedonic regression (linear and log-linear) and measuring the neighborhood benefits of rail transit accessibility	Assessed values (city property tax rolls)	➢ Age of home ➢ Size of home ➢ Lot size ➢ Residential zoning ➢ Distance to light rail ➢ Distance to highway ➢ Median income	San Francisco ➢ Study conducted for one station (Pleasant Hill). Property value decreased $1578 for every 100 feet further from station Queen, New York ➢ Study conducted for three stations in Queens and Property value decreased $2300 for every 100 feet further from station Portland, Oregon ➢ Property value increased $76 for every 100 feet closer (within a one-half to one mile radius) to three stations that were studied
Bollinger *et al.* (1998) Atlanta	Generalized least squares	Rental rates per square foot of office space in 1990, 1994, 1996	➢ No. of floors, average square feet per floor, building has parking ➢ Covered/deck parking ➢ Building age ➢ Highway within 1 mile ➢ Median income ➢ %population black ➢ Near shopping mall	➢ Rents are higher for building with greater total square footage more floors, higher average square feet per floor, a parking deck ➢ Newer building also command higher rents ➢ No evidence is found in support of the hypothesis that technological advances in telecommunications have diminished the role played by face-to-face agglomeration economies in determining the intra-metropolitan location of office firms
Haider and Miller (2000) Great Toronto Area	Hedonic regression (linear) with spatial autoregressive and the effects of transportation infrastructure and location	Residential property prices in 1995	➢ No. of rooms, bedrooms, bathrooms ➢ Parking capacity ➢ Distance from CBD ➢ Type of housing	➢ Other things being equal, the price of a unit will increase with an increase in the number of washrooms. This is also true for the number of bedrooms. An increase in parking capacity results in an increase in housing values ➢ Binary variables representing centralized air conditioning, detached housing, a pool, multiple fireplaces, and three story housing showed positive influences on housing values ➢ The price of housing decreases with the distance from the CBD, other things being equal ➢ For subway suggests that proximity to a subway line capitalizes into higher property values, other things being equal and adds approximately $4,000 to property value

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
(ten Siethoff and Kockelman, 2002) Texas, Austin	A two-step feasible generalized least squares and highway expansions	Commercial property assessment data 1982-1999	➢ Type of housing ➢ Retirement homes and day care centers ➢ Convenient store and gas station ➢ Small shopping store ➢ Showrooms and ware houses ➢ Bank branch offices ➢ Restaurant and grocery store	➢ In the total-value model single-family dwelling improvements are estimated to be worth an average of $43.50 per square foot ➢ Banks are most highly valued (per square foot), while retirement and day care centers, convenience stores, and gas stations are least valued (on the order of $15 to $20 per square foot, overall) ➢ Showrooms/warehouses were predicted to be worth significantly less than single-family homes ➢ The simple yearly time trends in all models are very positive. Marginally, these are on the order of $1 per square foot of structure/improvement and per square foot of land (an acre contains 43,560 square feet of land). However, the basic time-trend's positive coefficients are strongly tempered by the cumulative effects of construction-related educations. These are reflected in interactions with parcel size and, in the case of the improvement value model, with structure size ➢ Most properties were along the corridor itself, and the average of these distances across the data set was 0.19 miles. The distance reductions in value were predicted to be severe: at $511,000 per acre per squared-mile
Cervero and Duncan (2004) Santa Clara County, California	Two stage least squares with neighborhood composition	Residential transaction land value in 1999	➢ Land use mix ➢ Retail uses nearby ➢ Jobs and housing balance ➢ Single-family residential ➢ Racial mix ➢ Black neighbor ➢ Household income ➢ Job accessibility ➢ Commuter rail nearby ➢ Downtown distance ➢ LRT near large apartment ➢ Freeway distance	➢ All else being equal, a single-family parcel in a neighborhood with maximal mix (i.e. an entropy score of 1) could be expected to fetch around $8.70 more per square foot in the open market than a comparable one in a single-use neighborhood (i.e. an entropy score of 0) ➢ Having a balance of jobs and employed residents within 5 radial miles of a single-family parcel significantly added value ➢ Controlling for income effects, it appears that the prospects of developers earning bigger profits for parcels in areas zoned for higher density (typically multi-family) housing helped to drive up per square foot land values ➢ Being near a commuter rail station notably, the CalTrain system that connects to San Mateo County and the city of San Francisco-conferred value benefits to single-family parcels. On the other hand, no meaningful benefits accrued to single-family parcels near the much more modest, at-grade light rail system (that only serves parts of Santa Clara County) ➢ Disamenity effect was found with respect to being 'too close' (measured as a half-mile radius, in network distance) to a freeway

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Gao and Asami (2005) Setagaya Ward, Tokyo	Hedonic regression with influence of spatial features (GWR)	Transaction price of detached housing	➢ Building floor area / lot area ➢ Time to nearest station ➢ Width of road ➢ Remaining age of / house/lot area ➢ Within landscape zone ➢ Time to Shinjuku CBD by train ➢ Lot frontage, good road pavement ➢ No, of parking ➢ Sunshine duration ➢ Adjacent to park (dummy variable) ➢ Green space (dummy variable) ➢ Population density	➢ Population density had strong positive correlations with the GWR estimates of frontage and mixed land use, but strong negative correlations with the spatial variations of ratio remaining age to lot area. This implies that people living in densely populated blocks tend to think that the lot frontage and a large number of mixed land uses are more valuable, while the remaining building age and a large amount of trees are less valuable ➢ Mixed land use indicator was significantly to correlated to the GWR estimates, but was not significant in the global regression model
Ryan (2005) San Diego, USA	Hedonic regression, access to highways and light rail transit	Asking price (longitudinal data for 520 office properties and 500 industrial properties) from 1986 to 1995	➢ Straight-line distance of property to closet freeway on/off ramp, light rail transit station, the CBD ➢ Median income of census tract, sub-market dummy variables such as Central Bay, South Bay, East Bay ➢ Rentable area, no. of storey, age of building ➢ Vacancy rate	Office rent model ➢ No. of storey is significant in office rent models. Office space in higher buildings is more expensive than space in lower buildings ➢ The age of office building is also significant in determining office rents in each market areas indicating that older buildings rent for a discount ➢ Access to freeway provides the only consistent benefit for office firms across the three markets areas. 1% increase in the distance of an office property from the nearest freeway would correspond to an 11% decrease in office rents in the South Bay. In the East and Central areas, there would be 4% and 3% decrease respectively for every 1% increase in distance from a freeway ➢ Distance from transit station is also significant but with the unexpected positive sign on the coefficient in the East and Central markets areas. Office firms in these areas actually pay premiums to locate away from stations ➢ For distance to the CBD is only significant in the Central City market area while the South Bay and East areas do not depend on the San Diego CBF for services Industrial rent model ➢ Leasable area, property age and vacancy rate are significant in predicting industrial rents in each area ➢ Access to freeways is only significant for Central City industrial properties, but with an unexpected positive sign indicating that proximity to a freeway is a disamenity. A similar result is found for industrial firms and transit access in the Central City area ➢ Access to stations in the South Bay is significant and 1% increase in the distance of an industrial property from the station corresponds to 4.3% decrease in rents

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Du and Mulley (2006) Tyne and Wear Region, UK	Hedonic regression (linear), spatial heterogeneity (GWR) and transport accessibility	Land value in Wear and Tyne	➢ Property type ➢ No. of bedrooms ➢ Average score of the secondary school in 2003 ➢ %Ethnic minority ➢ %higher professional occupations ➢ %long term unemployment ➢ Public transport travel time to secondary school at peak hour ➢ Car travel time with capacity speed to employment ➢ Within 500m of metro station	Global regression ➢ An increase in 1 point of average secondary school score will lead to £950 increase in house price, holding everything else constant ➢ The value of one additional bedroom of flat/terrace/detached is worth £18,966/ £37,234 and £47,700 respectively. Flat and Terrace were expected to have less value than Semi while Detached was thought to be more expensive than Semi ➢ %ethnic and $unemployment were expected to decrease the property value. %high professional occupation and having a better school nearby would be expected to lift property value Local regression ➢ Although globally better public transport accessibility to secondary schools can add significant value to house price, it can be seen that, in most of the Region, the two variables appear to be unrelated. Only two areas the west end of Tyne and Wear Region and Newcastle central area emerge with such relationship with value added from £2,500 to £6,240. In the west end, bus access to secondary schools is associated with the positive premiums whilst in the other area public transport accessibility seems to be positively capitalized in relation to the metro access to secondary schools for pupils ➢ The south and the southwest of Tyne and Wear, where the estimate values are 0 as these areas are so far away from metro network that they are not accounted for in comparable areas by the local model. The area to the southwest of Tyne and Wear is not located in any relevant the catchment areas of metro stations and in the northeast of the Region, Whitley Bay, the closeness of metro stations raises the prices of properties by over £20,000
Armstrong and Rodríguez (2006) Eastern Massachusetts	Spatial hedonic price and the accessibility benefits of commuter rail	Single-family residential properties from four municipalities with commuter rail service and three municipalities without commuter rail service in 1992	➢ Usable living area ➢ No. of bedrooms and bathrooms ➢ Age of house ➢ Cape Cod-style house (dummy variable) ➢ Ranch-style house (dummy variable) ➢ Contemporary-style house (dummy variable) ➢ Other style (dummy variable) ➢ Lot size ➢ Population density, median income, pupil expenditures crime rate, tax rate ➢ Accessibility to commuter rail, highway	➢ Properties located in municipalities with commuter rail stations exhibit values that are between 9.6% and 10.1% higher than properties in municipalities without a commuter rail station ➢ Weak evidence of the capitalization of auto access time or walking time to the stations, suggesting that properties located within a one-half mile buffer of a station have values that are 10.1% higher than properties located outside of his buffer area and that an additional minute of drive time from the station is related to a decrease of 1.6% in property values ➢ Also indicate that proximity to commuter rail right-of-way has a significant negative effect on property values, which suggests that for every 1,000 ft. in distance from the commuter rail right-of-way, property values are between $732 and $2,897 higher, all else held equal

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Hess and Almeida (2007) Buffalo, New York, USA	Hedonic regression (linear and log-linear) and light rail transit	Assessed value of properties in year 2002 (residential properties)	➢ Assessed value per square foot ➢ Rail station proximity (straight-line distance and walking distance) ➢ Area of parcel, age of structure ➢ No. of bedrooms and bathrooms, single-family housing ➢ No. fire places ➢ Presence of basement ➢ Straight-line distance to CBD, the nearest park, Delaware Park ➢ East side dummy variable ➢ Crime rate, median income, population growth rate	All stations model ➢ Property located within a half-mile radius of rail stations is valued \$2.31 higher (using geographical straight-line distance) and \$0.99 higher (using network distance) for every foot closer to a light rail station ➢ An average home anywhere in the study area along the light rail line would generally be worth \$990 and \$2,310 more than the average home if it were within 100 0 feet of a station ➢ A property is located in East side which has the city's largest share of African-Americans and low income households , property values are likely to decrease by about \$28,000 ➢ The distance to CBD is the most statistically significant independent variable. For every foot closer to the CBD, there is a small decrease in property value at the rate of\$0.36 per foot ➢ Median income level followed by violent crime rate is the most statistically significant Individual stations models ➢ Proximity to some stations such as University station, Amherst station, Delavan-Canisius College station and Allen-Medical Campus station has statistically significant positive effects on property values ➢ Proximity to Utica station, Summer-Best station and Theater station has statistically significant negative effects on property values ➢ Lafayette Square and Humboldt-Hospital fail to show statistically significant effects in either model
Farooq *et al.* (2010) Great Toronto Area	Hedonic regression (linear) with box-cox transformation and spatial effects	Office space rent in 2005	➢ Vacancy rate of building ➢ Type of building (dummy variable) ➢ Total employees in office sector ➢ Distance to CBD ➢ Building within 500m from subway station (dummy variable) ➢ Building within 1km from regional transit station (dummy variable) ➢ Building near Toronto airport (dummy variable) ➢ Building in Mississauga downtown (dummy variable) ➢ % industrial land use ➢ %residential land use	➢ Spatial autocorrelation indicated that observations were found to have high autocorrelation with the neighboring observations ➢ The level of office space built-up in a business node has a positive impact on rents ➢ The vacancy rate of the building has a negative effect on the rents. For every 10% rise in vacancy rate, there is an average decrease of about 15 cents in rents ➢ For every 10% rise of residential area, there is a 13 cents decrease in the rents. Similar effect can be found in increase in industrial area ➢ Building that are located within 500m of subway station were found to have higher asking rents compared to other buildings. A premium of \$1 is added to asking rate for such office space ➢ Vicinity to regional transit stations also increased the asking prices. Office buildings located within 1 km of station have an asking rate that is higher by 63 cents ➢ With the increase in distance from the CBD, the asking price was found to generally decrease exponentially

Table 2 - 2 Hedonic Literature Review: Previous Studies in Developed Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Diao and Ferreira Jr (2010) Boston Metropolitan Area	➢ Hedonic regression with spatial autoregressive and impact of built environment ➢ Factor analysis for applied to select the built environment	Single-family transaction from 2004 to 2006	➢ Lot size, no. of parking, no. of fireplaces, living area ➢ Total no. of rooms, bedrooms, full bathrooms, half bathrooms ➢ Air conditioning system (dummy variable) ➢ Median income ➢ %white population ➢ Residential property tax rate ➢ Crime rate ➢ School scores ➢ Distance to park, churches, dentist, grocery stores, gym, hardware stores, shopping mall, restaurant, school ➢ Average road width, distance to highway, subway station, commuter rail station, bus stop, parking lots ➢ Average sidewalk ➢ Population density ➢ Built environment factors divided into 5 factor: distance to non-work destinations ➢ Connectivity, inaccessibility to transit and job, auto dominance, walkability	➢ Households would like to pay a premium for proximity to non-work destinations ➢ The positive sign of the connectivity factor suggests that households prefer good connectivity -an indicator of high-density, grid-type neighborhood. If the connectivity score increases by 1.364 units, which is one standard deviation of this factor across the study area, the property value will increase 2.18% or 8.22 thousand dollars for a house priced at 376.5 thousand dollars (the median value of all single-family housing transactions) ➢ The negative sign of the coefficients for inaccessibility to transit and jobs factor indicates households demand a discount for inaccessibility to transit and jobs. One standard deviation (1.014 units) decrease of this factor can increase the property value by 8.52%, or 32.07 thousand dollars for a house priced at 376.5 thousand dollars ➢ The coefficient of the auto dominance factor has a negative coefficient, which means households prefer locations far away from high-speed roads. The net effect is that property values are estimated to decrease 0.68% for one standard deviation (0.569 units) increase in the auto dominance factor
Duncan (2011) San Diego, CA, USA	Hedonic regression (log-linear) and transit-oriented development	Sale prices of Condominium in year 2000	➢ Square meters of floor space in the unit ➢ Age of the structure, no. of bedrooms and bathrooms, no. of garage spaces, view from unit ➢ No. of street intersections per hectare within 400m radius of a parcel ➢ Park and ride lot within 400m radius from the parcel, parcel is within 50m of a grade separated highway, network kilometers to the nearest Trolley station	➢ Station proximity has a significantly stronger impact when coupled with a pedestrian-oriented environment ➢ Conversely, station area condominiums in more auto-oriented environments may sell at a discount
Yan *et al.* (2012) Charlotte, North Carolina	Hedonic regression and a new light rail system	Sale price (single-family) From 1997 to 1998 From 1999 to 2005 From 2005 to 2007 From 2007 to 2008	➢ Age ➢ Height ➢ Central air conditioning ➢ Building grade ➢ No. fireplaces ➢ Distance to rail network ➢ Heated area	➢ Height, central air conditioning, no. of fireplaces, building grade and heated area are positively correlated with housing price every period ➢ Age variable becomes negatively correlated with house price, house prices tend to decrease with age in period 4. However this does not necessarily mean that older houses are not as valuable as newer houses ➢ The distance to station is positive but at a decreasing rate especially in period 4. At period 1,2 and , the positive coefficients indicate that houses tend to have higher values with a greater distance to the nearest station

Table 2 - 3 Hedonic Literature Review: Previous Studies in Developing Countries

Study	Model Structure	Type of Property	Determinants	Main Findings
So *et al.* (1997) Hong Kong	Hedonic regression (log-linear) and the influence of transport and Box-cox information	Sale price during 12 month period , from 1January 1994 to 31 December 1994	➢ Size, age ➢ Access to transportation to park, sea view, high floor ➢ Proximity to shopping centers ➢ Presence of sports facilities ➢ Swimming pools and car parks ➢ Distance to the nearest stations of MTR, buses and minibuses	➢ The valuation of a higher level floor turns out to be more expensive than that of a middle floor ➢ Presence of a park is significant indicating that parks are highly valued as a part of the environmental quality ➢ Higher floor are important factor in determining house prices ➢ Shopping center and sports facilities are also important factors ➢ Accessibility to minibuses merges as the most influential in determining house prices
Chau and Ng (1998) Hong Kong	Hedonic regression (linear and box-cox transformation) and the effects of improvement in public transportation (commuter rail)	Transaction residential price near Sha Tin and Tai Po stations	➢ Floor level ➢ Location dummy variable for the property near ShaTin station ➢ Dummy variable for built before august 1982 ➢ Floor area	➢ People are willing to pay a higher price for higher floor because of better views and a quieter environment ➢ Improvement in public transportation have a negative effect on the price gradient along the railway line
Tse (2002) Hong Kong	Hedonic regression (linear) with spatial autocorrelation and neighborhood effects	Transaction price of housing in Tsuen district	➢ Net floor ratio ➢ Age ➢ Floor ➢ Sea view dummy variable ➢ Availability of a clubhouse ➢ Accessibility to MTR ➢ Having one more bathroom	➢ The results from hedonic model and the model accommodated with spatial autocorrelation were similar except the variable of no. of bathroom ➢ An individual will be willing to pay more for a flat with a relatively higher net floor area ratio ➢ The accessibility to MTR station is highly significant indicating that the MTR effect has a strong and positive influence on house prices ➢ Higher floors are generally perceived to have better views than lower-level floors, therefore, the valuation of units on higher-floors turns out to be greater
Bae *et al.* (2003) Seoul, Korea	Hedonic regression and the new subway line 5 (semi-log and corrected heteroscedasticy)	Housing prices from the Budongsan Bank for the years 1989, 1995, 1997 and 2000	➢ Sale price ➢ Floor space of apartment, year in which was built, total households in apartment ➢ Parking space for household ➢ Type of heating ➢ Distance from the Greenbelt, the Han river ➢ Kangseo, Nambu, kangdong school district ➢ Population density, job density ➢ Distance from the subway line 5 ➢ Distance from the CBD ➢ Distance from subcenter Kangnam, Yeongdungpo	➢ Floor space, age and newer development were the most important structure variables on the price in every model while parking space was not ➢ The distance from subway line 5 is significant in 1989, 1995 and 1997 but not in the year 2000. This because the line had already been announced in 1989 and opened in 1997, the anticipatory price effects were reflected up to the year of opening, but had evaporated by 2000 ➢ The distance to the CBD is insignificant while distance to subcenter, Kangnam is highly significant. Furthermore, proximity to the subcenter Yeongdungpo, an industrial suburb, results in a heavy price discount that is consistently statistically significant ➢ Prices are negatively associated with population density but positively associated with employment density ➢ The school district showed that the Kangseo and Nambu school districts are much more attractive to households than the Kangdong school district

Table 2 - 3 Hedonic Literature Review: Previous Studies in Developing Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Lin and Hwang (2004) Taipei	➢ Hedonic regression and the price before and after the opening of the Taipei subway system ➢ Between traditional regression and fuzzy regression	Property transaction between 1993 and 1999	➢ Floor space, building age ➢ Distance from public facility and the CBD ➢ Economic growth rate ➢ Consumer price index ➢ Dummy (before and after subway opening)	➢ Subway opening significantly influences hedonic prices of floor space, building age, and distance from public facilities (schools or parks) ➢ The influences of subway system opening on hedonic price varies significantly according to different submarkets such as subway construction , location in city, position of property relative to subway stations, land use zoning, and building type ➢ Both traditional regression and fuzzy regression are useful, but generally, traditional regression is more persuasive than the other regression in analyzing hedonic prices
Kim and Zhang (2005) Seoul, Korea	Hedonic regression with spatial effect (deterministic and error term), i.e., OLS, SAR, SEM, SAC	Appraised land value per unit announced by Seoul Metropolitan Government (commercial land value)	➢ Distance to CBD ➢ Distance to subcenter ➢ Distance to station ➢ Dummy variable (Kangnam, Samsung, Yoido)	➢ Location premium in the CBD is the largest, that is in the Samsung is second highest, and that in the Kangnam and the Yoido are nest ➢ The economic benefits of station proximity in the overall city do not seem significant, they obviously exist in centers with high centrality and development densities ➢ After correcting the effect of spatial dependence of sample points, the study estimated a premium of $7.54 per meter associated with the transit stations that were located in the CBD ➢ The premium estimate was $5.88 for those stations located in the Samsung subcenter ➢ For Kangnam, another subcenter of Seoul, the premium estimate was $1.69 with a marginal level of statistical significance ➢ The importance of spatial sampling to the results of study that utilizes a conventional hedonic approach: a study heavily sampled from centers may find a significantly large premium over station proximity, whereas one concentrated in the suburbs may not find the same station benefit as in the inner city
Yiu and Wong (2005) Hong Kong	Hedonic regression and semi-logarithm hedonic with effects of expected transport improvements	Transaction housing price in Sheung Wan and Sai Ying district from May 1991 to March 2001	➢ Age ➢ Size ➢ Floor level	➢ There were positive price expectation effects well before the completion of the tunnel ➢ Results also showed significant increases in price well before the completion of the works, although not necessarily at the commencement of the works

Table 2 - 3 Hedonic Literature Review: Previous Studies in Developing Countries (cont.)

Study	Model Structure	Type of Property	Determinants	Main Findings
Lewis (2007) Jakarta, Indonesia	Hedonic regression (log-linear) and incidental truncation model with residential land price comparing between assessed and market value	Government assessed value and market value	➢ Land size ➢ Distance to CBD ➢ Class of road on which parcel is located ➢ Environmental conditions ➢ Non-existence (dummy variable)	➢ The use of market prices instead of appraised prices does not have much effect on the estimated land value gradient ➢ However, the employment of market prices has significant impact on the estimated influence of other determinants of land value. The effects and environmental conditions are especially noteworthy in this regard ➢ Furthermore, the land market in Jakarta values environmental conditions have to a significant degree, whereas such conditions have to impact on government assessments of land price
Pan and Zhang (2008) Shanghai, China	Hedonic regression and rail transit impacts	Residential Price	➢ Total floor area, lot size, age, finished interior ➢ Site density ➢ Presence of parks ➢ Shopping and retail facilities ➢ Schools ➢ Hospital ➢ Sport facilities	➢ Transit proximity premium amounts to approximately 152 yuan/m² for every 100 m closer to a metro station ➢ Residents are willing to pay a premium to be in the area with convenient neighborhood retail and commercial services ➢ Green space add value of values ➢ The presence of elementary school, however, does not have any statistically significant effects on residential unit price
Wei *et al.* (2012) Chengdu , China	Hedonic regression (linear) and impact of urban rail transit	Residential price from July 2010 to June 2011	➢ Distance to nearest station ➢ Distance to nearest bus stop ➢ Dummy variable nearby roads ➢ Estate types ➢ Total area, age of building ➢ Dummy variable far from river ➢ Dummy variable far from middle and primary school ➢ Green rate ➢ Property fee	➢ The residential prices far away from the downtown area were more likely to be found ahead than those around the city center and represented a far more sensitivity to the metro operation ➢ Regions that are closer to subway stations per meter from 1st ring to the third, the residential prices increased 0.91 Yuan/m2, 1.16 Yuan/m2 and 1.21 Yuan/m2 ➢ At the same time, Line 1 of Chengdu Metro has been increased a total number of 7.814 billion Yuan up to now of surrounding residential value

2.3.2 Hedonic Pricing Model Accommodating with Spatial Effects

Spatial econometrics Anselin (1981) and Cliff and Ord (1981) has grown in popularity over the past 25 years, and only recently has been applied in the area of urban and transportation development studies. There are two aspects of spatial econometrics, commonly referred to as spatial dependency and spatial heterogeneity (Anselin, 1981; Diao and Ferreira Jr, 2010; Farooq *et al.*, 2010; Fotheringham *et al.*, 2002; Pace and LeSage, 2009). More specifically, hedonic price model is estimate in a reference of the global regression which assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, it is natural to suspect the spatial effects association between land price and its attributes in particular proximity factors. Spatial dependence refers to a situation that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). The statistical test for spatial dependence was defined by Anselin (1981), the so-called spatial autoregressive model (SAR). While spatial heterogeneity refer to a situation that the measurement of a relationship depends in part on where the measurement is taken (Fotheringham *et al.*, 2002). The statistical test for spatial heterogeneity is based on the geographically weighted regression model (GWR). Some of the above studies have structuralized the spatial dependency with a simple regression for example Haider and Miller (2000); Kim and Zhang (2005); Armstrong and Rodríguez (2006); Chalermpong (2007); Chalermpong and Wattana (2010) and Farooq *et al.* (2010), while Gao and Asami (2005); Du and Mulley (2006); and Vichiensan and Miyamoto (2010) have focused on the spatial heterogeneity. Some studies have shed light on property value using both spatial dependency and heterogeneity.

For the spatial dependency, Kim and Zhang (2005) proposed model which is specified autoregressive expressions for lags and error components in the hedonic regression. The spatial hedonic models produce a more accurate and efficient estimator for transit's impact on commercial land values in Seoul, Korea. Unfortunately, the estimation results of spatial lag term of hedonic regression based on 85 records of office properties in Bangkok, Thailand implied that access to rail transit station exerts statistically significant, but relatively small impact on office rent. Specifically, office rent located within the district is higher than other those outside the district approximately 78 baht/sq.m (Chalermpong and Wattana, 2010). The spatial heterogeneity has been employed to examine the impacts of transport accessibility and land value in Tyne and Wear Region, UK and found that non-stationarity existing in the relationship. Some areas have a positive impact on land value in some areas but negative in others (Du and Mulley, 2006). Similarity, a study in Toronto, Canada also employed the spatial heterogeneity and indicated that access to transport infrastructure are significant in explaining the variation in the office rent (Farooq *et al.*, 2010). While, a study of Vichiensan *et al.* (2011) has applied both of spatial dependency and heterogeneity to examine the impact of the proximity to urban rail transit on the high-rise building for residence (Condominium and Apartment) in Bangkok, Thailand. The results model suggested that spatial effects exist in the data.

Literature in the impact of transit investment on property/land value found both positive and negative impacts of the urban rail transit and other transportation system. Often, the hedonic price model, applied the context of a simple regression, is used to examine the variations of the relationship between the property value and the proximity to the major transportation infrastructures especially rail stations. In general, the simple regression assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, it is natural to suspect the spatial effects association between land price and its attributes in particular proximity factors. Recently, literatures in urban studies have shed light on to the spatial association between property values and nearby properties tend to be similarly valued whereas the same type of properties at distant locations may be valued quite differently. They also focus on the local variation of the impact by incorporating heterogeneity or the so-called non-stationarity; a situation when parameter estimates vary with different spatial entity used.

2.3.3 Urban Rail Transit Investment Influences on Property Value

Over the past decades, it has become increasingly clear that the presence of urban rail transit system can increase property values by improving accessibility. The most widely used method of studying capitalization of rail transit accessibility has spawned innumerable applications of the hedonic pricing model, first introduced by Griliches (1961) and Rosen (1974) as stated. Bajic (1983) performed one of the earliest of these studies using a hedonic price regression model in order to identify the effects of a subway line in Toronto on the values of housing units. Empirical results indicated that the direct saving in commuting costs have been capitalized into housing values. Nelson (1992) determined surrounding the effect on the value of single-family homes of heavy-rail transit stations in residential neighborhoods in Atlanta, Georgia. Based on the results, it claimed that transit stations have positive price effects on homes in lower income neighborhoods but have negative impacts in high income neighborhoods. Gatzlaff and Smith (1993) examined the impact of the development of the Miami Metrorail system on residential property values proximate to its station locations using hedonic regression method. In this case, the result showed that the residential values were, at most, only weakly impacted by the announcement of the new rail system. Forrest *et al.* (1996) examined the relationship between the availability of commuter rail services and the pattern of house prices in an urban area, and to assess whether modernization of facilities can modify prices using a hedonic longitudinal theory in Manchester, England. The findings indicated that no discernible effect in the pattern of housing prices was found when comparing before and after project. So *et al.* (1997) attempted to analyze the importance of transportation including heavy rail and bus in determining housing prices in Hong Kong. Similarly in Hong Kong but different type of transportation infrastructure, Chau and Ng (1998) attempted to analyze the net change in the price gradient before and after the improvement of commuter rail to be assessed. The conclusion argued that expectations of transport improvements would be reflected in property prices before the actual completion of the improvements. Bae *et al.* (2003) investigated the impact of the construction of a new subway line on the nearby residential property prices. A hedonic study indicated that the proximity from the subway station has a statistically significant effect on prices only prior to the line's opening. Armstrong and Rodríguez (2006) attempted to estimate the accessibility benefits of commuter rail and they found that properties located in municipalities with commuter rail stations exhibit values that are between 9.6 percent and 10.1 percent higher than properties in municipalities without a commuter rail station in Eastern Massachusetts. In Buffalo, New York study showed with hedonic regression that every foot closer to a light rail station increases average property values by $2.31 (using geographical straight-line distance) and $0.99 (using network distance) (Hess and Almeida, 2007). Furthermore, they determined the effects of light rail transit on individual stations and proximity to some stations such as University station, Amherst station, Delavan-Canisius College station and Allen-Medical Campus station has statistically significant positive effects on property values while proximity to Utica station, Summer-Best station and Theater station has statistically significant negative effects on property values. A hedonic regression in Shanghai showed the premium land value of proximity to train station about 152 yuan/sq.m. for every 100 meter closer to a metro stations (Pan and Zhang, 2008). The summary of the impact of urban rail transit have increased a total number of 7.814 billion yuan on the surrounding residential values of Chengdu Metro Line 1 (Wei *et al.*, 2012).

A number of studies performed sought to distinguish between the accessibility benefits of rail transit and other transportation systems. Cervero and Landis (1993) compared the effects of office rents in areas surrounding rail stations in Washington D.C. and Atlanta with properties in freeway-oriented areas. The comparison suggested that the rail station areas enjoy a small rent premium over freeway-oriented offices. Ryan (2005) analyzed with simple regression model by comparing the importance of access to light rail transit and highway systems in estimating office and industrial property rents in San Diego area. The estimation showed that access to highway is significant effect to office rent while access to LRT is not.

Various rail transit modes are similarly important factors determining the degree of property value influence. In Santa Clara Country, California, Cervero (2004) explored the degree to which the benefit of having good access to transit gets capitalized into the market value of the land. Hedonic price models are used to find appreciable land-value premiums for multiple land uses in different rail corridors of San Diego County. Findings show that impacts appear to be corridor- and land-use specific. The most appreciable benefits were for condominiums and single-family housing near commuter-rail stations in the north county, multifamily housing near light-rail stations, and commercial properties near downtown commuter rail stations and light-rail stops in the Mission Valley. Elsewhere, commercial properties accrued small or even negative capitalization benefits.

Furthermore, Bollinger *et al.* (1998) used the proximity to station in explaining spatial variation in office rents in San Francisco, Queen and Portland. In San Francisco, the property value decreased $1,578 for every foot further from station while the value decreased $2,300 in Queen and only $76 in Oregon.

2.3.4 Determinants of Property Value: Property Characteristics

As stated, hedonic studies have been use to estimate property values of various structural characteristics. There are the characteristics that have appeared most often in hedonic pricing models. Conclusions for the property characteristics are summarized as below.

Age of structure is the variable most often included in hedonic pricing models. Home age tended to reduce property values by about $443/year or a one percent increase in home age leaded to a 0.05 percent decrease in home sale price in BART (Lewis-Workman and Brod, 1997). Likewise, age and newer development were the most important structure variables on the price (Bae *et al.*, 2003). Similarly, age is also used to determine in commercial property. For example, Bollinger *et al.* (1998) found that a newer office space building will be able to command higher rents from tenants. Likewise, the age of office building was significant in determining office rents, indicating that older buildings rent for a discount (Ryan, 2005). Though, age variable became negatively correlated with housing price, house prices tended to decrease with age, this did not mean that older houses are not as valuable as newer houses (Yan *et al.*, 2012).

Certainly, size of structure is also the most important factor used to determine how much a property is worth. Building size was the most important determinant of home prices with a value of about $1,100/m2 or a one percent increase in home size leaded to a 0.62 percent increase in sale price in BART (Lewis-Workman and Brod, 1997). Hess and Almeida (2007) area of parcel was the most statistically significant independent variable and positively influences property value. For every square foot increase in the lot area, the property value increased about $4. Besides, the number of rooms such as bedrooms and bathrooms are positively impact on the property values (Armstrong and Rodríguez, 2006; Du and Mulley, 2006; Duncan, 2011). For each additional bathroom, the property value increased by about $25,000 (Hess and Almeida, 2007). But no significance was found on the bathroom variable (Forrest *et al.*, 1996). Furthermore, an increase in parking capacity resulted in an increase in housing values (Gao and Asami, 2005; Haider and Miller, 2000) but it was not found in Bae *et al.* (2003).

Another important variable that influence on the property value is the floor level. The valuation of a higher level floor turned out to be more expensive than that of middle floor (So *et al.*, 1997). Also, Chau and Ng (1998) indicated that people are willing to pay a higher price for higher floor because of better views and a quiet environment.

Other variables that can find in some studies such as type of heating and air-conditioning system, quality and interior design, type of buildings, sea view and vacancy rate (Forrest *et al.*, 1996; Haider and Miller, 2000; Pan and Zhang, 2008; So *et al.*, 1997; Tse, 2002; Yan *et al.*, 2012). For example, the vacancy rate of building has a negative effect on the office rents, for every 10 percent rise in the vacancy rate, there was as average decrease of about 15 cents in rents (Farooq *et al.*, 2010).

2.3.5 Determinants of Property Value: Location and Neighborhood Characteristics

Not only property characteristics have been considered to property or land value impacted, but also the characteristics of location and neighborhood. What constitutes the characteristics of location and neighborhood? Previous literatures point to access and accessibility, zonal density (e.g. population density and employment density), school quality, median income, crime rate and other variables as seen in the Table 2 - 1 and Table 2 - 3.

Location refers to the specific placement of a property which affects the prices. Specifically, the location affects the prices that reflect character of the area. The property is a part of a neighborhood and should be viewed in the community setting. Since the property is fixed in location, it differs in terms of its surroundings. Facilities of transport, education, health care, shopping and recreation are factors to be considered when investigating the property prices. Property in good locations and neighborhoods commands higher sale prices than those in bad locations and neighborhoods. As mentioned above, that is, spatial variation in property prices can be explained by differences in location and neighborhood attributes in space. Conclusions for the location and neighborhood characteristics are summarized as below.

2.3.5.1 Access and Accessibility

In transportation, access and accessibility refers to ease of reaching destinations with people in places that are highly accessible reaching many other activities. General accessibility is derived in terms of distance, time taken and cost of reaching each destination by different modes of transport.

A number of studies have been carried out on the significance of accessibility to employment which mostly refers to the distance to CBD. McDonald and McMillen (1990) used distances to CBD subcenters to predict residential land values in Chicago and they found that land values decline 16 percent per mile with distance to the CBD. In Manchester, UK, a distance to CBD, in particular, was included in the locational characteristics to assess the significance of the property and the results found that the property price increased with distance from the CBD (Forrest et al., 1996). every 100,000 additional jobs that could be reached within 30 minutes raised per square foot values by $1.21 in the case of peak-period travel over the highway network and by $6.47 for travel on transit network (Cervero and Duncan, 2004). Likewise, other things being equal, the price of housing decreased with the distance from the CBD, indicating consistently higher property values in neighborhoods further from downtown (Haider and Miller, 2000). Having a balance of jobs and employed residents within 5 radial miles of a single-family parcel significantly add values (Cervero and Duncan, 2004). They found a decrease in the value at the rate of $0.36 per foot further away from the CBD (Hess and Almeida, 2007). Kim and Zhang (2005) compared the effects of location premium among the CBD, and subcenters, namely, Kangnam, Samsung and Yoido and the results showed that location premium in the CBD is the largest, that is in the Samsung is the second highest, Kangnam and Yoido. Longer distances to the city's subcenters are associated with lower prices of residential units, for every kilometer increases in the distance to XuJiaHui, the price would drop by 4.0 percent (Pan and Zhang, 2008). However, access to the CBD was not significant in any of the industrial rent models in San Diego (Ryan, 2005). Likewise, the distance to the CBD was insignificant in determining prices, while distance to subcenter, namely Kangnam, was highly significant, but proximity to another subcenter, namely Yeongdungpo an industrial suburb, resulted in a heavy price discount (Bae *et al.*, 2003).

Not only does the employment accessibility variable, but also the easy access to non-work activities such as shopping center, bank branch offices, green space or park, hospital, airport, etc. are found to be influencing factor impact on the property values. For example, So *et al.* (1997) revealed that non-work activities, e.g. the presence of shopping centers and sport facilities, are important factors in determining house prices. The shopping mall, one of the attractiveness of the location, that was found the highly significant and uplift the office rents (Bollinger *et al.*, 1998). Banks were most highly valued per square foot while retirement and day care centers, convenience stores and gas stations were least valued (on the order of $15 to $20 per square foot, overall) (ten Siethoff and Kockelman, 2002). Lin and Hwang (2004) indicated that reduces distance from public facilities increases and promotes property values. As seen in Pan and Zhang (2008), the residents were willing to pay a premium to be in the area with convenient neighborhood retail and commercial services.

Another important variable in term of access and accessibility is the distance to different transportation infrastructures such as road network, highway and freeway and bus stop. For example, accessibility to minibuses merge as the most influential in determining house prices (So *et al.*, 1997). Wei *et al.* (2012) concluded that when the unit gets closer to bus stop per meter, the price raises 10 yuan/m^2. A one percent increase in distance from the highway leads to a 0.10 percent increase in home sale price (Lewis-Workman and Brod, 1997). Similarly, proximity to a highway interchange has a positive effect on office rents (Bollinger *et al.*, 1998). Likewise, Armstrong and Rodríguez (2006) suggested that as the distance to the closet highway interchange increases, property values increase.

2.3.5.2 Neighborhood Amenity

Among variables describing neighborhood quality, median income level was statistically significant and it had positive impact on property values in Queen (Lewis-Workman and Brod, 1997). Cervero and Duncan (2004) revealed that every $10,000 increase in mean household income was associated with a $1.67 per square foot increase in multi-family parcels in Santa Clara County while every $100 increase in the median annual household income is associated with a $36 increase in property value in Buffalo, suggesting that houses are more likely to sell for a higher price in affluent neighborhoods (Hess and Almeida, 2007).

Furthermore, the zonal density also employed to measure the tendency of property value. For example, Population and employment density were both significant; prices are negatively associated with population density but positively associated with employment density (Bae *et al.*, 2003).

2.3.5.3 Other Variables

The school quality, flooding, level of security, percent of population black, racial composition, crime rate, the noise level, and number of fireplaces in the neighborhood were also chosen to be a representative attributes of locations and neighborhoods effect on the property values with their methods. Previous research has provided mixed evidence including large positive, small positive as well as negative effects.

Crime rate is also explaining the neighborhood quality; higher violent crime rate has negative impact on property value: every 1 percent increase in violent crime rate is associated with a decrease in property value of about $292 (Hess and Almeida, 2007).

The school district data showed that the Kangseo and Nambu school districts are much more attractive to households that the Kangdong school district (Bae *et al.*, 2003). The performance point of the closet secondary school was that an increase in one point will lead to £950 increase in house price on average, holding everything else constant (Du and Mulley, 2006). However, Pan and Zhang (2008) indicated that the presence of elementary schools does not have any statistically effects on residential unit price.

Percent of population black had no effect on the property values (Bollinger *et al.*, 1998). Higher shares of African-Americans and Hispanic households also tended to lower the value of multi-family parcels (Cervero and Duncan, 2004).

2.4 Theoretical and Empirical Studies of Residential Location Decision

Models of residential location choice are important tools used in analyzing urban policy with respect to transportation and urban land use planning. Over the past four decades, researchers developed the mathematical modeling of residential location decision behavior. Discrete choice models have a long history of application in residential location choice decision was introduced by McFadden (1974). Most discrete choice models are based on the concept of utility maximization. The utility maximization is generated based on the concept that individuals or households attempt to get the greatest value possible from expenditure by trade-off. With the discrete choice models, the multinomial logit (ML) has been the most widely used structure due to its simple formulation form and ease of estimation with choice sets of alternatives.

There is an abundance of studies that attempt to understand the residential choice behavior through discrete choice models. These studies are common and/or different in the model structure utilized, the significant choice determinants and the findings. Some of these studies are summarized in Table 2 - 4.

2.4.1 Residential Location Choice Model

Some studies have focused only on residential location choice (Clark and Burt, 1980; Gabriel and Rosenthal, 1989; Hunt *et al.*, 1994; McFadden, 1978; Quigley, 1985; Timmermans *et al.*, 1992). For example, Hunt *et al.* (1994) constructed a model of residential location choice in Calgary, Alberta, Canada, using a stated preference experiment. The emphasis of the study was an order of preference for a set of hypothetical residential location alternatives which described by specifying a monthly charge, number of bedrooms, travel time to work, travel time to a shopping center, and proximity to light rail transit (LRT). All of the attributes were found to have statistically significant effects on the attractiveness of residential locations. Specific findings were that travel time to work is worth approximately 25 Canadian dollars (C$25) per hour, travel time to work is about two times as important as travel time to shop, an additional bedroom is equivalent to approximately C$155 per month, and being within walking distance of an LRT station is worth about C$217 per month. Both household income and family size were found to have significant influences. These results provide empirical evidence that the transport system influences the attractiveness of residential locations.

Some studies (Deng *et al.*, 2003; Gabriel and Rosenthal, 1989; Miller and Quigley, 1990; Sermons, 2000; Waddell, 1992) have focused on location choice for specific demographic groups (such as single worker, female and male households, Caucasian households). For example, Deng *et al.* (2003) examined whether racial differences in residential location outcomes are among the factors that contribute to the large racial differences in homeownership rates in major US metropolitan areas. The empirical evidence suggests that African-American residential location outcomes are associated with lower than expected racial differences in homeownership. Therefore, after controlling for neighborhood, racial differences in homeownership are larger than originally believed, and the ability of racial differences in endowments to explain homeownership differences is more limited.

However, the choice of residential location is very complex and also relies on many other choices. For example, people who prefer to commute by transit would choose to live near a transit station. Likewise, people who prefer walking may be consciously choose to live in walkable neighborhoods. Similarly, people living in sprawling areas have to rely on cars to conduct their daily activities. This interdependency has lead researchers to model residential location choice jointly with other choice dimensions such as car ownership (Bhat and Guo, 2007; Lerman, 1975; Lerman, 1976; Pinjari *et al.*, 2011; Weisbrod *et al.*, 1980), bicycle ownership (Pinjari *et al.*, 2011), commuting mode (Abraham and Hunt, 1997; Kim *et al.*, 2003; Ng, 2008; Pinjari *et al.*, 2007), work location (Rivera and Tiglao, 2005; Sener *et al.*, 2011; Waddell *et al.*, 2007), school location (Barrow, 2002), housing mobility (Borgers and Timmermans, 1993; Ioannides, 1987; Lee *et al.*, 2010; Onaka and Clark, 1983), and housing attributes (Abraham and Hunt, 1997; Guevara and Ben-Akiva, 2006; Hoshino, 2011; Hunt *et al.*, 1994; Kim *et al.*, 2003). Besides, few studies attempted to model the residential location choice incorporating the individual's life style and preferences. For example, Krizek (2006) refined a framework to analyze household choices relating to three dimensions of lifestyle: travel patterns (including pedestrian activity), activity participation, and neighborhood characteristics in Minnesota, while Cao *et al.* (2006) examined that the connection between the built environment and pedestrian behavior may be more a matter of residential location choice than of travel choice.

Table 2 - 4 Previous Studies in Residential Location Decision

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Lerman (1976) Washington, USA	Residential location choice with car ownership and commute model choice	Multinomial logit model (ML)	➢ Housing structure and cost ➢ Size variable ➢ Commute time ➢ Income dissimilarity ➢ Racial composition and residential density ➢ Per pupil school expenditures ➢ Municipal and property tax ➢ Geographic indicator ➢ Generalized shopping price by mode	➢ Households generally prefer areas with low density and high school expenditure ➢ Single-worker households are more affected by the level shopping accessibility than multi-worker households ➢ Aversion of whites to non-whites is greater for multi-worker households than single-worker households ➢ Income segregation is more pronounced for single-worker households than multi-worker households
Weisbrod *et al.* (1980) Minneapolis/St. Paul, Minnesota	Residential location, the role of transportation, neighborhood quality	Nested logit model (NL)	➢ Distance from previous residence ➢ Crime ➢ Residential density ➢ Proximity to industrial land ➢ Zonal median income ➢ Household size ➢ % Elderly ➢ Teacher/pupil ratio ➢ Property tax	➢ 5% reduction in auto commute time has an effect equivalent to 1.5% reduction in monthly rent, 3.8% decrease in home value, or 28% decrease in crime rate ➢ 5% reduction in bus commute time has an effect equivalent to 0.3% decrease in monthly rent, 0.5% decrease in home value or 3.8% decrease in crime per rate ➢ Local school quality is not significant ➢ No reduction in auto travel time or bus travel time could compete with the locational effect caused by the propensity of households with children to choose single-family, detached houses ➢ Households tend to locate in areas with low residential density
Boehm (1982) Michigan	Housing choice , tenure and neighborhood quality	Nested logit model (NL)	➢ Size, quality, ➢ Family size, age of head, marital status, income ➢ Housing value ➢ Race	➢ A larger family size increases the probability of choosing a larger house ➢ A larger family with own large house less likely to live in high income neighborhoods ➢ The relative price of high versus low quality housing has a significant impact on the choice probability. ➢ Blacks are less likely to live in high income neighborhoods
Quigley (1985) Pittsburgh metropolitan area, USA	Choice of dwelling, neighborhood and public services	Nested logit model (NL)	➢ Structure type ➢ Age of structure ➢ Condition of structure ➢ No. of bathrooms ➢ No. of bedrooms per person ➢ Monthly income minus rental payment ➢ Proportion of homeowners ➢ Median income ➢ Auto commute time ➢ Transit commute time ➢ Racial composition ➢ Size measure ➢ School expenditure per person ➢ Municipal expenditure per households	➢ Single detached dwelling are preferred to duplexes; both are preferred to apartment dwellings ➢ Households preferred more income and lower housing prices ➢ Households preferred more space and baths ➢ Fraction of homeowners and median rent are not significant determinants ➢ A given reduction in auto commute time has three or four times the effects of an equivalent reduction in compute time by transit ➢ Black households are more likely to choose neighborhoods of larger fraction of blacks ➢ Households prefer to live in towns where school expenditures and others public expenditures are lowers

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Timmermans *et al.* (1992) Netherlands	Residential location choice with dual earner households	Multinomial logit model (ML)	➢ Distance to work location, income per month, no. of working days ➢ Type of dwelling ➢ Cost per month, tenure, no. of bedrooms ➢ Size and location of dwelling ➢ Distance to public transport, and frequency	➢ Households prefer detached and semi-detached houses to row houses and apartments ➢ Size attributes are insignificant ➢ Younger households prefer living in larger cities ➢ Public transport related variables are not statistically significant
Waddell (1992) Dallas and Tarrant countries, Texas	Residence, workplace, and housing tenure	Joint multinomial logit model	➢ Travel time to work, Dallas CBD, Fort Worth CBD ➢ Share of regional rental, owner housing supply, mean age, % housing, % black population, percent Hispanic population, population density, Employment density ➢ Income, age, senior, family status ➢ Workplace characteristics	➢ Despite higher average levels of education than Hispanics, blacks are much more likely to live in racially isolated neighborhoods, to face more resistance in the workplace and consequently to commute farther to work than other racial groups ➢ Distaste for commute is balanced with a preference for larger homes and lower densities farther from the city centers
Waddell (1993) Dallas-Fort Worth	Workplace choice in residential location model	Nested logit model (NL)	➢ Travel time to work, Dallas CBD, Fort Worth CBD ➢ Share of regional rental, owner housing supply, mean age, % housing, % black population, percent Hispanic population, population density, Employment density ➢ Income, age, senior, family status ➢ Workplace characteristics	➢ Household heads appear to choose residences and workplaces so as to balance their distaste for commuting with a preference for lager homes and low density to the extent their incomes allow ➢ Higher incomes and family status tend to increase the preference for larger housing at the cost of longer commutes ➢ Socioeconomic status, stage of life cycle, and race , each affect choice of residential location
Hunt *et al.* (1994) Calgary	Residential location choice	Multinomial logit model (ML)	➢ Money cost per month ➢ No. of bedrooms ➢ Commute time ➢ Travel time to shopping center ➢ Light rail transit station within walking distance	➢ Travel time for work trips is more than twice as important as the equivalent time for shopping trips ➢ Smaller households tend not to place as high a value on larger dwellings ➢ Perceived importance of being within walking distance of LRT by households located within walking distance of LRT in reality is more than twice as high as that by other households
Freedman and Kern (1997) Philadelphia, Chicago, San Francisco, Detroit and Houston	Residence and workplace choice in two worker households	Multinomial logit model (ML)	➢ Earnings opportunities of husbands and wives ➢ Presence of small children ➢ Commuting time ➢ Household income	➢ Earnings opportunities of both husbands and wives affect household utility and location in all five cities ➢ The presence of small children always increases the impact of wives' earnings, but the effect is significant only in Philadelphia ➢ Commuting times have significant negative impacts for both spouses in all cities ➢ Residential attractiveness of the suburbs appears to exceed that of the city for all two-worker households in all cities and the disparity increases consistently with household income, but only sporadically with the presence of children

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Levine (1998) Minneapolis Region	Residence	Nested logit model (NL)	➢ Commute time for worker 1 ➢ Commute time for worker 2 ➢ Housing unit ➢ Housing units boarded up ➢ Housing units occupied by owners ➢ Median housing price ➢ % school ➢ Urban and suburban ➢ Density	➢ Except for low and moderate income, single-worker households, the choice processes are better represented by the nested model ➢ Housing price does not constitute a barrier to high income group's locational decisions ➢ Low income households sensitive to long commute ➢ Low and moderate income, single-worker households are most attracted to added density plus affordable housing
Ben-Akiva and Bowman (1998) Boston, USA	Residential location choice	Nested logit model (NL)	➢ Expected utility of household members' daily activity schedule ➢ Composite impedance measure for commute ➢ Violent crime rate, residential density ➢ Income remaining after housing expense ➢ School education performance ➢ Proximity to industrial acreage ➢ Town's expenditure on culture and recreation ➢ Residential tax rate	➢ Work's accessibility has strong and positive effect on residential choice ➢ The composite impedance for commute explains residential choice behavior better than the expected utility of activity schedule ➢ Households are less likely to reside in locations with high crime rate, high density, and high housing price relative to their income level ➢ School performance, industrial acreage, expenditure on culture and recreation, tax rate, and CBD indicator are not significant choice determinants
Nechyba and Strauss (1998)	Residential location choice	Multinomial logit model (ML)	➢ Per pupil school spending ➢ Effective property tax rates ➢ Distance from CBD ➢ %commercial land use ➢ Median rooms ➢ %houses built since 1980 ➢ Marginal price of an additional room ➢ Private goods consumption	➢ Both local school spending and community entry price are significant determinants ➢ Increase in commercial activities and distance from the CBD raise the probability a community is chosen ➢ Increase in crime rate decreases the probability is chosen ➢ Higher housing price decreases the probability is chosen ➢ Higher housing quality increases the probability is chosen
Chattopadhyay (2000) Chicago	Residential location, dwelling, neighborhood and city attributes	Nested logit model (NL)	➢ Number of room, age, lot size, garage, air-condition ➢ %of white population ➢ Median income, Distance to downtown ➢ Tax, operating expense per pupil, expenditure per capita ➢ Within 5 mile radius from business district	➢ Households prefer more rooms, newer houses and houses with air-condition and prefer to live in a neighborhood with more concentration of white population, higher median income ➢ Households choose to live in a city with less property tax rate, higher school spending, and higher municipal spending ➢ Whites opt for less number of room, older houses, and bigger lot size than non-whites, but like to live in a neighborhood with more white population, higher median income, farther from CBD, and at a location with less air pollution ➢ Large families prefer more rooms, older houses, and bigger lots than small families ➢ Large families opt for a neighborhood with higher percentage of white population, lower median income, farther from the CBD and at a location with less air pollution

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Sermons and Koppleman (2001) San Francisco, USA	Residential location choice between male and female commute behavior	Multinomial logit model (ML)	➢ Commute time ➢ Housing costs ➢ Size variable ➢ Racial composition	➢ Difference between female and male commute time sensitivity is the most profound in households with children ➢ Households with a male professional worker, a female non-professional worker, and where female changed her workplace after the last residence change show the largest disparity in commute time sensitivity
Earnhart (2002) Town of Fairfield	Housing choice (actual housing, hypothetical and combined)	Multinomial logit model (ML)	➢ Age, lot size, bedroom, bathroom, interior space, style ➢ Natural feature (land and water) ➢ Flooding	➢ Households are more likely to select new house with more bathrooms, interior space or larger lots ➢ Per person interior space has an effect on high income and medium income ➢ Households are more likely to buy house exposed to 100-year flood ➢ Households tend to locate adjacent near water-based or land-based feature than natural feature
Barrow (2002) Washington, DC	School choice through relocation	Multinomial logit model (ML)	➢ Average SAT point ➢ Adjust rent ➢ Distance from DC ➢ Per capita country expend net for education ➢ Crime rate ➢ Land area ➢ Median rooms per housing unit ➢ Proportion owner-occupied housing units ➢ Proportion of persons in poverty ➢ Number of DC Metro stations ➢ Proportion of the white ➢ Number housing units	➢ Households are more likely to locate in areas with higher rent and high SAT scores reduce the probability a household locates to a given area. ➢ Household with children locate in higher school quality areas than households without children ➢ Households have strong preferences for living in areas with households of the same race and the same class. ➢ Households with children are less sensitive to crime and Metro stations than households without children and highly educated households with children put much more weight on locating in neighborhoods with higher shares of college educated people.
Kim *et al.* (2003) Oxford Shire, UK	Residential location choice	Multinomial logit model, Stated preference approach	➢ Housing price ➢ Travel time to work, travel cost to work, travel cost to super market ➢ Housing density ➢ Location ➢ School quality ➢ Noise level	➢ The monetary value of one minute of travel time to work is equal to £6,339 with regard to the housing value and that one pence of travel cost to work is trade off with £883. ➢ Houses in the city are not preferred and that living in the city decreases one's utility. ➢ Quality school is significant on the residential location choice and the monetary values are £67,000 with regard the housing price. ➢ Lower density and lower level of noise are preferred
Tayyaran *et al.* (2003) Ottawa-Carleton Region, Canada	Residential location choice, telecommuting and intelligent transportation systems	Multinomial logit model (ML) with stated preference	➢ Level of telecommuting, travel delays ➢ Monthly housing cost, no. of rooms ➢ Travel time to work, travel time school ➢ Access to outdoor recreation	➢ The level of telecommuting tend to lead the higher probability of residential location choice ➢ Households tend to live in the areas that provide them the reliable travel time to work

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Deng *et al.* (2003) Philadelphia, USA	Residential location, racial differences in homeownership	Nested logit model (NL)	➢ Size variable ➢ Variation in price ➢ Racial composition ➢ income composition ➢ Zonal fixed effects of housing price ➢ Zonal equity risk ➢ Geographic indicator	➢ For white owner occupants, unmarried individuals without a high school education avoid location with high concentrations of blacks, expensive quality adjusted housing prices, and high equity risk. they also prefer central city over suburban locations ➢ As education level rises, white homeowners lose their aversion to locations with high minority concentrations, high price levels and high equity risk ➢ Black households are more likely to reside in locations with a high percentage of minorities and the effect increases with education ➢ Black renters are more likely to live in locations with a high percentage of minorities and less likely to live in locations with equity ➢ The likelihood of residing in zones with high amenity levels increases with education level ➢ Employment access makes a location more attractive, but its affect falls with the probability of unemployment
Miyamoto *et al.* (2004) Sendai, Japan	Residential location choice with spatial effect	➢ Logit (L) ➢ Logit with autoregressive deterministic term (LAD) ➢ Mixed logit with autoregressive error term (MLAE) ➢ Mixed logit with autoregressive deterministic and error term (MLADE)	➢ Travel time to work ➢ Distance between previous house and present house ➢ No. of window in a house ➢ No. of person in household ➢ No. of license driver in household ➢ No. of worker in household	Case 1 – Choices with large difference in relative distance ➢ Household tends to locate closer to workplace ➢ Household tends to select new house nearer to their previous house ➢ Household tends to live in the area with similar household characteristic ➢ Housing developer usually build similar house unit in a certain area ➢ Spatial autocorrelation exist in this case and must be specified in the modeling ➢ The MLADE model has the best performance over the other reference models Case 2 – Choices with small difference in relative distance ➢ Locations that are far from each other will not have any similarity ➢ The specification of spatial autocorrelation is not significant in LAD and MLAE model ➢ The specification of spatial autocorrelation is not significantly reliable in MLADE because the estimate value does not satisfy the condition Case 3 – All choices are closely located ➢ The spatial autocorrelation is not significant because there is not enough relative distance between zones

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Bhat and Guo (2004) Dallas Country, Texas, USA	Residential location choice with spatial effect	➢ Mixed multinomial logit (MMNL) ➢ Mixed spatially correlated logit (MSCL)	➢ Zonal area size and population density ➢ Zonal land use structure such as percentage of zonal area devoted to single family housing, office space, retail use ➢ Zonal demographics and cost variable such as average household income in zone, household size, household cost ➢ Commute time between work zone and candidate residential zone ➢ Commute distance between work zone and candidate residential zone ➢ School quality measures ➢ Racial composition ➢ Accessibility to socio-recreation, shopping and employment opportunities	<u>Case 1 – The MMNL model results</u> ➢ Households are more likely to locate in larger zones than smaller zones ➢ Household are more likely to locate in zones with high population density due to better housing availability ➢ The absolute difference between the zonal median income and household income confirms the income segregation phenomenon ➢ Proximity to the employment location of the worker in the household is an importance factor in residential location choice ➢ African-American households are located in areas with poor work accessibility and all households prefer locations that offer good accessibility to shopping ➢ The housing cost and school quality variables are not statistically significant. the lack of influence of these two variables may be a consequence of the resolution used to represent location in this study <u>Case 2 – The MSCL model results</u> ➢ Commute time has a higher (mean) effect in the MSCL model relative to other variables, as can be observed from the higher ratio of the coefficient on commute time to other coefficients ➢ The mean negative effect of the percentage of zonal area occupied by multifamily households in a zone is also higher (relative to other variable effects) in the MSCL model ➢ 77% of households prefer zones with higher population density, 23% prefer zones with low population density ➢ 80% of households prefer zones with lower percentage of zonal area devoted to multifamily, 20% prefer zones with higher percentage ➢ 75% of individuals like to live closer to their work place, 25% prefer location farther aw
de Palma *et al.* (2005) Paris Region	Household residential location choice and housing price	Multinomial logit model (ML)	➢ Same district before move ➢ Price ➢ No. of railway station and subway station ➢ Average time by private and non-private car ➢ Distance to highway ➢ Household size and household status ➢ Population density, employment density	➢ Households tend to move in the same district or neighborhood in which they live before. ➢ Housing price has a negative effect on location preference for a commune. This effect increases with age of household head and decrease as the household income increase. Also, the older heads of households are more sensitive to price and the richer households are less sensitive to it ➢ The no. of metro stations in a commune increases the probability of location but the no. of railway stations decreases it ➢ Households tend to live in the same social category. ➢ Total no. of employment is not significant

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Rivera and Tiglao (2005) Metro Manila, Philippines	Residential location choice, workplace choice and mode choice of two-worker households	Nested logit model (NL)	➢ Accessibility index for work trips ➢ Population density ➢ %low income ➢ Total number of housing units ➢ Distance between workplace ➢ No. of workers at workplace of worker 2 ➢ No. workers at workplace of worker 1 ➢ Travel cost to work for worker 2 ➢ Travel cost to work for worker 1 ➢ Travel time to work for worker 2 ➢ Travel time to work for worker 1	➢ The population density has little influenced because there is not much decrease in population in the inner core of region ➢ They want to work in areas where there is a large population of workers because of more opportunities for job ➢ Worker 1 (highest income in household) and 2 use share rides during to-work and to-home trips so distance between the workplace of 2 workers is minimized ➢ The work 1 is not given more priority in the location choice decision than work 2
Bina *et al.* (2006) Austin, Texas	Residential location choice, transportation with the case of apartment dwellers	➢ Weighted least squares ➢ Binary choice experiment ➢ Ordered probit	➢ No. of bedrooms and bathrooms, rent, interior size, commute to work/school, travel time to store and mall ➢ Household size, no. of workers, children, licensed drivers, vehicles, household income ➢ Age, married, race, occupation, education level, employment status ➢ Distance to CBD, travel time to work, travel cost, population density, employment density median income, no. of bus stop	➢ Larger households and married couples tend to prefer lager apartments and more parking, single households are more likely to opt for a shorter commute time and a downtown location. ➢ Larger households tend to value apartment enhancements over access improvements and those with children tend to opt for a nearby park ➢ Households with many workers are attracted by the light rail option ➢ High income households tend to value park view over bus stop proximity and a newer complex over nearby shopping, ➢ Non-Caucasian households are more interested in shorter travel times than in better apartment features ➢ More highly educated persons are more likely to choose reduced travel times and a downtown location. And retired persons tend to be more impressed by shopping access than by newer apartments
Pinjari *et al.* (2007) San Francisco	Residential sorting, the built environment and commute mode choice	Joint model	➢ No. of households, household density, employment density ➢ Residential land area, land use mix ➢ Recreation accessibility ➢ Total drive commute time and cost ➢ Street block density, bicycle facilities density, transit access ➢ Median income ➢ Housing value ➢ Caucasian population, African-American population, Hispanic population	➢ Households are more likely to locate in zones with high household density, but seniors are less likely. ➢ High employment density zones are less likely to be chosen for residential location, except for lower income households who may be compelled to choose lower cost housing in such locations. ➢ Households desiring to live in single housing units are more likely to locate in zones with a higher fraction of such a housing stock ➢ A higher recreational accessibility is associated with a greater likelihood of locating residence in a particular zone.

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Bhat and Guo (2007) San Francisco, USA	Residential location, auto ownership levels and built environment	Joint multinomial logit model	➢ Zonal size, household density, employment density, residential land area ➢ Recreation accessibility ➢ Drive commute time, drive commute cost ➢ Street block density ➢ Bicycle facilities density ➢ Transit availability, transit access time to stop ➢ Median income, average housing value	➢ Households without seniors locate in zones with high household density but households with seniors shy away from high housing density ➢ Middle and high incomes households prefer zones with a low employment density while low income households are indifferent to employment density ➢ Regional accessibility measures do not appear to be important determinants of residential location choice ➢ The only statistically significant variables correspondent to recreational accessibility. Middle and high income households locate themselves in good recreational accessibility. ➢ Households locate to reduce their drive commute time. High income households choose residential close to work locations.
Waddell *et al.* (2007) Washington, DC, USA	Residential location choice and workplace choice	Multinomial logit (MNL) with joint model	➢ household size ➢ household income ➢ vehicle ownership ➢ children ➢ number of jobs ➢ AM HW total transit/walk travel time ➢ AM HW drive alone travel time	<u>Case 1 – Residential choice model</u> ➢ Households with more children will be more likely to heavily consider the implication of schools on residence location, and given a particular residential choice, may be more tied to a residence location than would other households ➢ Households with higher income are more likely to choose their residential location first, relative households with less income ➢ higher income choose to stay in affluent communities with high levels of amenities and relatively low property taxes ➢ households with more than one car are more likely to choose their residential location first, relative to other households ➢ households with low vehicle ownership, especially in the one worker sample, may be younger and low-income than the average household in which case they are more likely to rent and lo locate in housing that is relatively accessible to their workplace <u>Case 2 – Workplace choice model</u> ➢ the higher the number of jobs in a zone, the more is the likelihood of the zone being chosen as the work place ➢ the travel times by auto and transit were again significant and in the expected direction, with the same pattern of larger relative magnitude of the auto travel time effect compared to transit. <u>Case 3 – Joint model of residence, workplace and latent choice structure</u> ➢ the coefficients on log(income) and population density became insignificant in the joint model ➢ The work location component of the joint model is substantially and significantly higher than unity ➢ 80.8% of households choose residential location first, and then choose the work location conditional on the residential location

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Prashker *et al.* (2008) Tel Aviv	Residential location choice, gender and the commute trip to work	Multinomial logit model (ML)	➢ Travel to work by car and bus ➢ Occupation ➢ Population density and employment density ➢ Distance to school ➢ Socioeconomic status	➢ Sensitivity to distance decreases as income rises for both genders, but the sensitivity to distance for women is higher than for men at all income levels ➢ Travel time by bus has a lower effect than by car and gender is not show the significant ➢ Households tend to live in high socioeconomic neighborhoods
Cho *et al.* (2008) Mecklenburg country, North Carolina, USA	Residential location choice and accessibility to employment subcenters	Heteroscedastic logit	➢ No. of children, income level, no. of vehicles, no of workers ➢ %black residents ➢ Access to closet subcenters, cumulative access to each subcenters, minimum access to each subcenters, neighborhood types ➢ Walkability and local accessibility ➢ Assumed taxes, school districts and other local public goods are similar across the study area	<u>Case 1 – All income households</u> ➢ Households are more likely to choose areas with more high-income household acres and with a lower percentage of black residents ➢ subcenters 4 and 8 and more likely to live close to subcenter 5 where is spatially disperse business sectors, such as financial services, various other services ➢ Access to closet subcenter and cumulative access to all subcenters show less significant impacts than those with access to individual subcenter <u>Case 2 – High-income households</u> ➢ Household attributes, income and no. of vehicles emerged as significant affecting the residential location decisions ➢ Access to the closet subcenter and cumulative access to all subcenters are not statistically significant. <u>Case 3 –M-income households</u> ➢ Median-income households taste in location vary based on household characteristics, such as number of children, income, and no. of vehicles ➢ Access to the closet subcenter does not significantly influence residential location choice, but cumulative access to all subcenters is a significant determinant <u>Case 4 – Low-income households</u> ➢ Low-income households tend to choose their residence closer to the closet subceners specializing in transportation, utilities and warehouse
Vega and Reynolds-Feighan (2009) Dublin, Ireland	Residential location choice and travel-to-work mode choice	Cross-nested logit (CNL)	➢ Property prices ➢ Age ➢ Education and employment status ➢ Number of cars ➢ Household size ➢ Household type ➢ Nature of occupancy ➢ Travel time car and public transport in minutes ➢ Travel costs car and public transport in euro	<u>Case 1 – CNL estimate results for the monocentric city</u> ➢ Older individuals are found to be more likely to live closer to the CBD than younger individuals ➢ Single individuals, with a higher probability of choosing residential location further from the CBD ➢ Larger families are more likely to select alternatives further away from the CBD <u>Case 2 – CNL estimate results for suburban employment</u> ➢ The number of cars available in the household is now significant ➢ Individual working at peripheral suburban locations as more likely to live further away from the CBD

Table 2 - 4 Previous Studies in Residential Location Decision (cont.)

Study	Dimension Models	Model Structure	Determinants (Housing and Neighborhood)	Main Findings
Lee *et al.* (2010) Central Puget Sound Region	Residential location choice with influence of work and nonwork accessibility	Multinomial logit model (ML)	➢ No. of residential unit ➢ Same district before move ➢ Population density ➢ Annual income, household status ➢ Travel time to workplace, ➢ No. of job	➢ Middle income and low income households have negative utilities is likely due to the correlation between housing size and price unlike high income households the utility derived from lager homes. ➢ Confirms the prominent role of work access on residential choice and no. of shopping types highlights the value of access to nonwork activities
Hoshino (2011) Setagaya, Shibuya and Meguro in Tokyo	Residential choice behavior	➢ Multinomial logit model (ML) ➢ Mixed logit model with conjoint experiments	➢ Rent per month ➢ Area of living space ➢ Building age ➢ Building class ➢ Walking time to nearest station ➢ Commuting time by train ➢ Proximity to shops or supermarkets ➢ Proximity parks or green space ➢ Proximity to hospitals or welfare facilities	➢ Households prefer to live in condominium type dwelling. Approximately 60% of households want to live in a residential zone and 70% prefer to be close to shops and supermarkets ➢ Transport convenience related variables have impact on residential choice. But the proximity to shops or super markets is greater than the other two proximity variables. ➢ Interestingly, while proximity to shops or supermarkets have positive effect, households o not favor nearby commercial land use
Pinjari *et al.* (2011) San Francisco, USA	Residential location choice, auto ownership, bicycle ownership, and commute mode choice	➢ Joint multinomial logit model ➢ Multi-dimension choice modeling, simultaneous equation model	➢ No. of households, household density, employment density ➢ Land use structure ➢ Median housing value, median income ➢ Race composition ➢ No. of physically active recreation centers, No. of natural recreation centers ➢ Street block, bicycle facility density ➢ Total commute time	➢ Household density and employment density have no significant impact on residential location choice except for certain demographic segments such as households with seniors and children or high income households ➢ Zones with commercial or mixed uses are less likely to be chosen for residential location ➢ People of similar income levels and race tend to cluster together when it comes to residential location ➢ Street block density is negatively associated with residential location choice, in particular for high income group ➢ Households prefer to live in locations with good infrastructure for bicycling or walking ➢ Households try to locate within close proximity of their workplaces.
Sener *et al.* (2011) San Francisco, USA	Residential location choice with spatial effect	➢ Logit (L) ➢ Generalized spatially correlated logit (GSCL) ➢ Spatially correlated logit (SCL)	➢ Land use mix ➢ Households in zone ➢ fraction of Caucasian population interacted with Caucasian dummy variable ➢ Absolute difference between zonal median income and household income ➢ Absolute difference between zonal average household size and household size ➢ Average of median housing value ➢ No. of physically active recreation centers such as fitness centers, sport centers, dance and yoga ➢ Highway density	➢ Households tend to be positively inclined to locate in zone with larger numbers of households ➢ Caucasian households locate themselves in predominantly Caucasian zones ➢ Clustering effect are observed with respect to zonal demographics and housing cost ➢ Households tend to locate in zones with similar income levels and household sizes ➢ The number of activity centers increases in a zone, households are more likely to reside in such a zone ➢ Residential location choice is positively impacted by the availability of transit between the home and work zones

As identified in Table 2 - 4, it is common for the previous studies to apply the discrete choice structure, namely multinomial logit (Gabriel and Rosenthal, 1989; Lerman, 1976; Sermons and Koppleman, 2001; Waddell, 1992). Another discrete choice family treating the residential location choice along with other choice dimensions is to apply the nested logit model such that one of the levels in the nesting structure corresponds to the residential location choice (Ben-Akiva and Bowman, 1998; Chattopadhyay, 2000; Lee *et al.*, 2010; Vega and Reynolds-Feighan, 2009). Furthermore, several studies have indeed estimated more advanced discrete choice model more than standard logit model to incorporate spatial correlation. For example, Bhat and Guo (2004) had developed model within the Generalized Extreme Value (GEV) while Miyamoto *et al.* (2004) proposed model which is specified with autoregressive expressions for deterministic and error components of utility.

2.4.2 Urban Rail Transit Availability in Residential Location Choice Decision

Over the past decades, it has become increasingly clear that living near the urban rail station is the determinant factor in residential location choice theory. Walmsley and Perrett (1992) studied and reviewed the effects of 14 rapid transit systems in the UK, France, USA and Canada. They found that in Washington D.C. homes near stations appreciated at a faster rate than similar homes further away. Similarly, they provided the evidence that the effects of LRT in the Portland, Oregon may indicate the beginning of a self-selection in residential location choice wherein persons desiring rail transit chose to live where it is available (van Wee *et al.*, 2002). Likewise, (Bhat and Guo, 2007) attempted to understand whether the association between built environment and travel behavior related variables is a true reflection of underlying causality to the relationship between the built environment and the characteristics of people who choose to live in particular built environments in the Alameda County in the San Francisco Bay Area. They found that among the local transportation network measures, it was clearly that households prefer to live in zones with transit service availability and with smaller access times to transit stations, but they did found the relationship between the demographic variables of households and the sensitivity to transit availability and access time to stations. Israel and Cohen-Blankshtain (2010) explored suburbanization and sprawling effect of commuter rail transit on the rural exurbia of the Tel Aviv metropolis by analyzing its effect on residential location decisions and the results indicated the suburban rail system was an influencing factor in residential location choice behavior of households. Interestingly in de Palma *et al.* (2005) developed the model of residential location choice with endogenous housing prices and traffic for the Paris Region. Comparing results founded that the metro stations in a commune increase the probability of location but the railway stations decrease it. These results because metro stations may be more likely than railway stations to be located within clusters of shopping and service employment or adjacent to major cultural attractions. Barrow (2002) showed the positive effect of the number of metro stations in Washington DC on the location probabilities for White households but decrease for African-American Households.

2.4.3 Determinants of Residential Location Choice: Housing Amenity Variables

Housing affordability, measured by housing price, price-to-income ratio, and rental is very popular in many researches as an essential concept in explaining the attractiveness feature for a residential zone. As most households make choice of residential within budgetary constraints, housing price is a significant factor in household location choice. Coefficients of affordability variable (price interacted with levels of income) are negative and significant for low and medium income households, but not significantly for the high income groups (Levine, 1998). Similarly, the household income is substantially interaction with the housing price (Lee *et al.*, 2010). Likewise,de Palma *et al.* (2005) found that housing price has a negative effect on location preference for a commune, however, this effect increases with the age of the household head and decreases as the household income increases. In the other word, the older heads of households are more sensitive to price and the richer households are less sensitive to it. As suggested by Tu and Goldfinch (1996) found results for single-young person households and households with dependent children are strongly influenced by relative price. Waddell (1992) found a positive, though small, elasticity for housing price for white workers. This is contradictory to the observation made by (Deng *et al.*, 2003) that white homeowners lose their aversion to locations with high price levels as education levels rises.

For the housing size, housing type and number of rooms vary by household characteristics, e.g. household size, family status, socioeconomic status, and gender. A larger family size increases the probability of choosing a larger house (Boehm, 1982; Chattopadhyay, 2000; Hunt *et al.*, 1994). Waddell (1993) found that higher income and bigger family size tend to increase the preference for larger housing at the cost of longer commutes. Furthermore, Quigley (1985) found that while single detached dwellings are preferred to duplexes, both are preferred to apartment dwellings and households also preferred more space and number of baths. Timmermans *et al.* (1992) showed that households prefer detached and semi-detached houses to row houses and apartments. Larger households and married couples tend to prefer larger apartments, but non-Caucasian households and retired persons are more interested in other amenities than in better apartment features (Bina *et al.*, 2006). As a results were found in Chattopadhyay (2000) , which showed that Caucasian households opt for less number of rooms, older houses and bigger lot size than non-whites.

Other features identified to have positive effect on residential choice behavior include the presence of large kitchen, central heating and garden (Tu and Goldfinch, 1996), interior styles (Earnhart, 2002).

2.4.4 Determinants of Residential Location Choice: Location and Neighborhood Variables

Location refers to the specific placement of a house which affects the preference of the individual. Since the house is fixed in location, it differs in terms of its surroundings (neighborhood and community setting). Facilities of transport, education, health care, shopping and recreation are factors to be considered when choosing the house in each location. Good locations and neighborhoods command higher demand than those in bad locations and neighborhoods.

2.4.4.1 Access and Accessibility

The concept of access and accessibility in choice of residential location behavior has been studied by many researchers. Empirical research has given variable results about how access and accessibility to transportation, other type of opportunities (employment, shopping and recreation) or land use affects residential behavior. Ben-Akiva and Bowman (1998) and Lee *et al.* (2010) found that employment accessibility has strong and positive effect on residential choice behavior. Likewise, households tend to live in the areas that provide them the reliable travel time to work (Tayyaran *et al.*, 2003) and closer to workplace (Miyamoto *et al.*, 2004). Similarly, Bhat and Guo (2004) concluded that proximity to the employment location of the worker in the household except African-American households is an importance factor and 75 percent of households like to live closer to their work, but 25percent prefer location farther away. Furthermore, the monetary value of one minute of travel time to work is equivalent to £6,339 with regarding to the housing value. However, Waddell (1993) found that households do not prefer high employment accessibility.

Not only does the employment accessibility variable, but also the easy access to shopping or recreation opportunities are found to be importance factors in analysis of residential location choice behavior. Households prefer locations that offer good accessibility to shopping (Bhat and Guo, 2004; Pinjari *et al.*, 2007). Several studies found differing effect of access to shops (Bhat and Guo, 2007; Bina *et al.*, 2006; Tu and Goldfinch, 1996). Singer young person households prefer to live near shopping centers, while young couples prefer to live far from the shopping areas (Tu and Goldfinch, 1996). Comparing between age of housing and shopping accessibility, retired persons tend to be more impressed by shopping access than by newer apartment, but high income households tend to value a newer complex over nearby shopping mall (Bina *et al.*, 2006). Bhat and Guo (2007) found that only middle and high income households locate themselves in good recreational accessibility. Furthermore, travel time to work is more than twice as important as the equivalent time for shopping (Hunt *et al.*, 1994). And the proximity to shops or supermarkets is greater than the transport convenience-related variables (Hoshino, 2011).

Another important consideration in choice of residential location is access to alternative modes of transportation (Barrow, 2002; Bina *et al.*, 2006; Cho *et al.*, 2008; de Palma *et al.*, 2005; Hoshino, 2011; Hunt *et al.*, 1994; Sener *et al.*, 2011; Tayyaran *et al.*, 2003) while Timmermans *et al.* (1992) found that distance to public transport is not statistically significant. The level of telecommuting tend to lead the higher of probability of residential location choice (Tayyaran *et al.*, 2003). As Hunt *et al.* (1994) found in their analysis, residents who already live within walking distance of light rail transit perceive the ease of access to transit more than twice as important as other households do. Similarly, walking distance to station has negative effect on location preference for a commune (Hoshino, 2011). Likewise, it was clear that households prefer zones with transit availability and with smaller access time to stations, but it cannot find any demographic differences in the sensitivity (Bhat and Guo, 2007; Sener *et al.*, 2011). However,de Palma *et al.* (2005) found the differing effect, the number of metro stations in a commune increases the probability of location but the number of railway stations decreases it while the households with children are less sensitive to the metro stations than households without children (Barrow, 2002). Furthermore, low income households tend to choose their residence closer to transportation (Cho *et al.*, 2008),but high income households tend to value park view screen over bus stop proximity and also non-Caucasian value transit access as more important by students and lower level of education (Bina *et al.*, 2006). In addition, Freeway access is rated higher by females, Hispanics, Latinos and African-Americans, those of lower educational attainment and those without children at home.

2.4.4.2 Neighborhood Amenity

Where considered, the median income is often captured in residential choice models in order to explain the term of segregation. Chattopadhyay (2000) suggested that households choose to live in a neighborhood with higher median income. The same as in Barrow (2002), households have strong preferences for living in areas with the same class. The absolute difference between the zonal median income and household income confirms the income segregation phenomenon (Bhat and Guo, 2004). Similarly, high socioeconomic neighborhoods emerged as significant affecting the residential location decision (Cho *et al.*, 2008; Pinjari *et al.*, 2011; Prashker *et al.*, 2008; Sener *et al.*, 2011).

From the perspective household characteristics, there are several factors that can influence the effect of zonal median income variables on residential choice decision. Initially, dingle-worker households are more pronounced in income segregation than multi-worker households (Lerman, 1976). Blacks are less likely to live in high income neighborhoods (Boehm, 1982). In contrast, whites like to live in a neighborhood with higher median income, but large families opt for a neighborhood with lower median income (Chattopadhyay, 2000).

For the population density, while Lerman (1976); (Weisbrod *et al.*, 1980); Ben-Akiva and Bowman (1998); Kim *et al.* (2003); Vega and Reynolds-Feighan (2009) showed that households are less likely to reside in locations with high density, Waddell (1993); (Bhat and Guo, 2004) and (Pinjari *et al.*, 2007) found that high population density is preferred by households. In addition, Bhat and Guo (2004) pointed out that 77 percent of households prefer zones with higher population density, only 23 percent prefer lower population density. Furthermore, they found the differing effect of population density for different population groups. Lower density is especially attractive for large households, while low-to-moderate-income households and single-worker households are most attracted to high density (Levine, 1998). Moreover, all else being equal, African-American households (Waddell, 1993), households without senior (Bhat and Guo, 2007; Pinjari *et al.*, 2007; Pinjari *et al.*, 2011) and households without children (age of 5-15 years) (Pinjari *et al.*, 2011) are more likely to locate in areas of high density.

For the employment density, several studies indicated that households prefer to locate themselves in areas of low employment density (Pinjari *et al.*, 2007; Pinjari *et al.*, 2011; Waddell, 1993). But the total number of employment is not statistically significant in residential location choice behavior (de Palma *et al.*, 2005; Waddell *et al.*, 2007). The effect of employment density has also been found for different population groups as the population or household density. For instance, high employment density zones are less likely to be chosen for residential location, except for lower income households who may be compelled to choose lower cost housing (Bhat and Guo, 2007; Pinjari *et al.*, 2007; Pinjari *et al.*, 2011).

2.4.4.3 Other Variables

As stated in the table, the safety of residential neighborhoods, in term of crime rate, is used to generate the model of residential. The lower crime rate contributes to increasing the attractiveness of residential location (Ben-Akiva and Bowman, 1998; Nechyba and Strauss, 1998; Weisbrod *et al.*, 1980).

Another variable associated with choice of residential location is indicated by the racial composition variables. Households often show strong preference for locations with a high percentage of households of the same race (Chattopadhyay, 2000; Lerman, 1976; Onaka and Clark, 1983; Pinjari *et al.*, 2011; Quigley, 1985). Furthermore, despite higher average levels of education than Hispanics, blacks are found to be much more likely to live in racially isolated neighborhoods than Hispanics (Waddell, 1993).

It is intuitive that school quality should play an important role in the residential location decision, in particular for families with children. The empirical findings about effect school quality have been mixed. Households generally prefer areas with high school expenditure (Lerman, 1976). Also, households choose to live in a city with higher school spending. As suggested in (Nechyba and Strauss, 1998), one percent increase in the level of per pupil spending on education raises the probability of the average households choosing a particular community by anywhere from 1.65 percent to 3.06 percent. In addition, households with children have strong preferences for living in higher school quality areas than households without children and, high SAT scores reduce the probability a household locates to a give area (Barrow, 2002).

Unlike, households prefer to live in towns where school expenditure is lower this because they are far more likely to choose residences outside the city (Quigley, 1985). Ben-Akiva and Bowman (1998) and Bhat and Guo (2004) also indicated that school performance is not significant choice determinants in residential location decision.

The land use mix, noise level, number of markets, number of waste disposal centers, number of children's playground, number of recreation facilities, number of nursery and school, number of parking facilities, and flooding were also chosen to be a representative attributes of locations and neighborhoods effect on the residential location choice with their methods (Bhat and Guo, 2004; Bhat and Guo, 2007; Cho *et al.*, 2008; de Palma *et al.*, 2005; Kim *et al.*, 2003; Lee *et al.*, 2010). Previous research has provided mixed evidence including large positive, small positive as well as negative effects.

2.4.5 Determinants of Residential Location Choice: Household Characteristics

An investigation into the relationship between housing preferences and choice of residential location is associated with the different groups of households. Household composition, namely size of household, income level, level of education and employment status, is an important variable to consider with regard to housing amenities and location decision. For example, the size of household creates a differing demand on housing. The larger size family of households, the larger size of housing they prefer (Bina *et al.*, 2006; Boehm, 1982; Hunt *et al.*, 1994; Waddell, 1993).

Age, marital status and number of children are also important household composition variable to capture the model of residential location decision (Barrow, 2002; Cho *et al.*, 2008; de Palma *et al.*, 2005; Hunt *et al.*, 1994; Prashker *et al.*, 2008; Sermons and Koppleman, 1998; Waddell, 1992; White, 1988).

Another variable is level of education, which to some extent reflects the internalization of the society. As educational attainment increases, people tend to internalized more housing and location (Barrow, 2002; Gabriel and Rosenthal, 1989; Nechyba and Strauss, 1998; Prashker *et al.*, 2008). For example, white homeowners lose their aversion to locations with high price levels as education levels rises.

Furthermore, travel behavior and car ownership are the critical mediating link in the residential location choice. Households with low vehicle ownership, especially in the one worker sample, may be younger and low-income than the average household in which case they are more likely to rent and lo locate in housing that is relatively accessible to their workplace (Waddell *et al.*, 2007). The number of cars available in the household is strongly significant on the making decision in residential location (Vega and Reynolds-Feighan, 2009).

2.5 Previous Studies of Land Development in Bangkok Metropolitan Region

Urban transportation policy in Bangkok Metropolitan Region is mostly driven by addressing traffic problems due to the traffic congestion has become one of the most serious problems. To address these problems, the Government has focused mainly on increasing the supply of road infrastructure by expanding road systems and developing rapid transit system like skytrain, subway, and bus rapid transit. However, the impacts of transportation development projects are still rare. More specifically, these impacts are seldom part of a project's goal and are usually not intentional. Consequently, the purpose of this section is to review and summarize the existing researches relating to land development and transport studies in order to identify the extent of land development impacts in Bangkok Metropolitan Region.

2.5.1 Land Development Studies

Previous study, In Bangkok, Hara *et al.* (2005) examined the land use changes in the suburbs of Bangkok, and focused on the land transformation that is inherent on deltas where the land use shifting from paddy fields to urban dwellings. The research was conducted through aerial photograph interpretation and field measurement, then, calculated the areas of land use changes by overlays of the digital land use maps in each period, 1967, 1979, 1987 and 1995 as can be seen in Figure 2 - 1. The result revealed that the present urban land uses are linked with the past agricultural land use patterns, or canal systems, sized and shape of land parcels.

Malaitham (2010) has investigated the change in building stock in study area. The existing tall buildings, including office buildings, hotels, condominium, etc., in the areas along Sukhumvit Road were investigated. They are presented in three-dimensional graphics with the aid of Google Earth and Google Sketch Up as illustrated in Figure 2 - 2.

- The first group consists of those existed before BTS started its construction in 1992, as colored in green.
- The second group includes those constructed during the construction of BTS from 1992 to 1998, as colored in red.
- The third ones are those constructed after BTS opened in late 1999, as colored in blue.

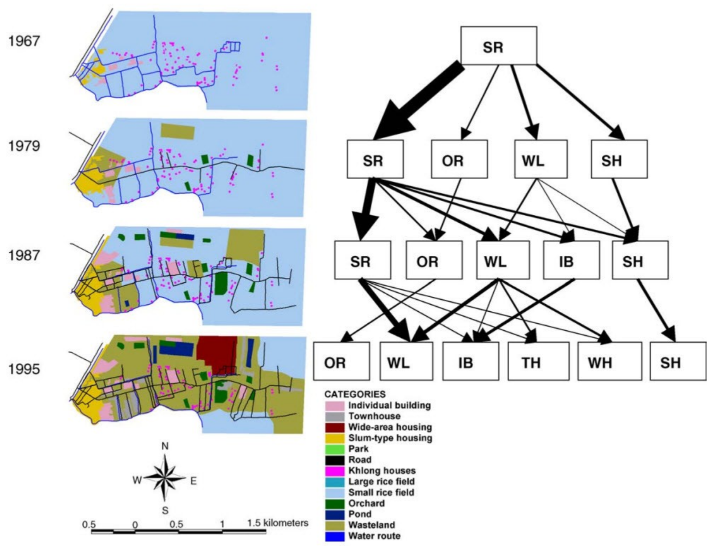

Figure 2 - 1 Detailed of Land Use Changes
Source: Hara *et al.* (2005)

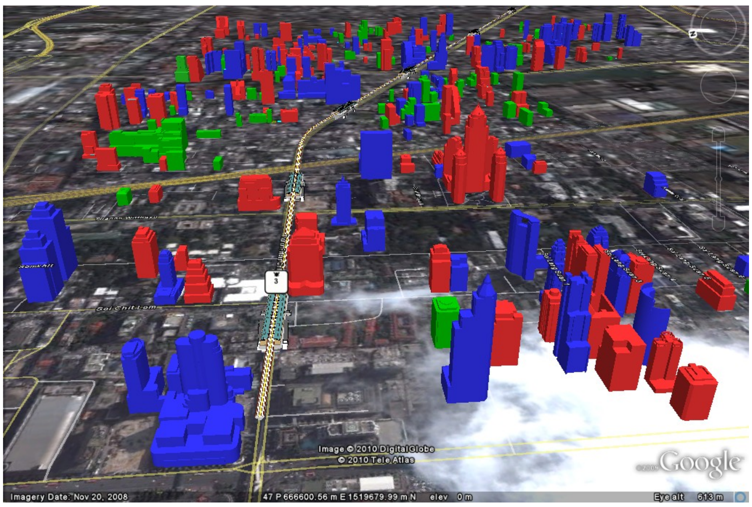

Figure 2 - 2 Existing Building in 2009
Source: Malaitham (2010)

2.5.2 Rising of Land Price and Property Value Studies

Due to its popularity, the urban rail transit system has large influence on its surrounding area, especially around the stations. After the BTS railway in Bangkok has opened, land price along the corridor has remarkably increased especially at the transfer stations.

Crane *et al.* (1997) compared between Bangkok and Jakarta using a hedonic model for household-level data how the poor value environmental amenities and basic infrastructure access and found that slum housing prices do reflect differential in public service access.

Wisaweisuan (2001) aimed to examining spatial; behavior of land price in Bangkok during the 1990s. A consideration of sample data of 101 land parcels was used to estimate the relationship between price and their attributes such as distance to CBD, distance to subcenter, dummy variable for land used and so on. Moreover, the location in Bangkok was divided into 2 groups of subcenter in order to investigate the spatial behavior of land price. The results show that the Bangkok land market differentiated and can be segmented into sectors by transportation routes. In addition to access, difference in quality of infrastructure and transportation routes in different area produces different impacts on land prices as well as the extent of suburbanization.

Chalermpong (2007) studied on the impact transit improvements on property prices and developed the hedonic price model and spatial regression models to examine this relationship in Bangkok. The 226 observations of multi-family residential properties along the BTS Sukhumvit Line were collected from September 2004 to March 2005. Estimation results indicated that the premium of transit accessibility is adding to the property value approximately \$10 for every meter close to the station.

Vichiensan *et al.* (2007) showed that land price has remarkably increased around the stations. It is especially pronounces around Asok transfer station for BTS and MRT lines. In samples of historic land prices are obtained from the Treasury Department. A contour plot change of the official land value assessment during the year 1992 and 2006 is in Figure 2 - 3. Each interval represents 10,000 baht change in land price between two points in time. The narrow gap contour shows abrupt change in land price during 14 years, before and after BTS service.

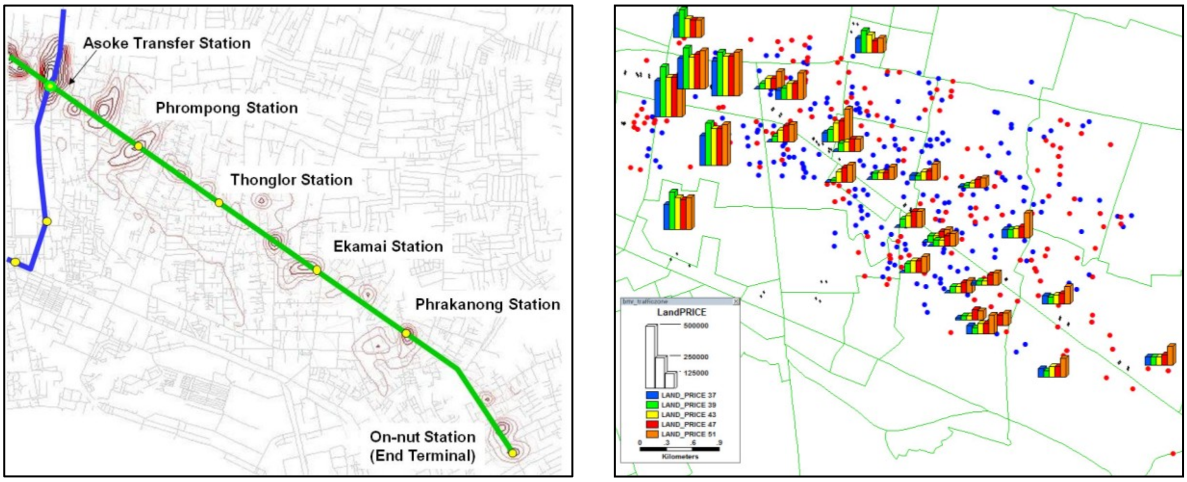

Figure 2 - 3 Impact of Railway Development
Source: Vichiensan *et al.* (2007) and Malaitham (2010)

Chalermpong and Wattana (2010) estimated the results of spatial lag term of hedonic regression based on 85 records of office properties in Bangkok, Thailand implied that access to rail transit station exerts statistically significant, but relatively small impact on office rent. Specifically, office rent located within the district is higher than other those outside the district approximately 78 baht/sq.m.

Further, the change in land value was observed by considering the official land value appraisal at representative locations beside Sukhumvit Road. It is found that land value has appreciated substantially as can be seen in Figure 2 - 3 (Malaitham, 2010). Notice the stations of the two railway lines in the figure. The color bars at representative locations compare the appraised land values at different years. It is apparent that land value is appreciated in the later year after the railway has opened in 1999.

2.5.3 Choice of Residential Behavior Studies

Dawcharoen (1996) intended to investigate household decision making behavior on residential location and lot size in relation to commuting behavior. Basic utility maximization was used in the analysis of household's trading off behavior on residential location and lot size. The sample sizes included in the estimation of the study were 108 observations of workers whose office were located in Silom district of Bangkok because this research hypothesized that employment location plays the major role in households' residential location decision. Estimation findings confirmed that the higher income workers prefer to locate their residences farther from the CBD the lower income workers. Moreover, Household residing in the larger size of housing unit, located its residence at father distance from the CBD, i.e., with the longer commuting time.

Choocharukul *et al.* (2008) investigated psychological effects of travel behavior on residential location choice by commuters using structural equation from two cities in Thailand, Bangkok and Ubon Ratchathani. The results claimed that the person who preferred life with frequent car in the future would be less likely to stay in an environment with convenient public transport. Furthermore, some psychological aspects towards modes of transport were found to be important factors foe choice of future residential area.

Ketraungroch (2008) investigated how residential location patterns among different income households in Bangkok changes as a consequence of transport improvement, in the period of pre and post rail transit system availability. The data set used is the sampled of 1,445 households in Bangkok from the household Socio-Economic Survey (SES) conducted by National Statistical Office (NSO) in 1998 and 2004. Each sample includes residential location sub-district, household's transportation expenditure and average household income. The empirical results show that residential location pattern chosen by households who face two competing alternative choices among transit, bus and car in 1998 and 2004 are similar. That is car, as an alternative to the bus and transit, allows the higher income groups to enjoy time cost saving advantages and encourages them to locate in a more distant area. When comparing different competing transit choices in 2004, between bus and car as well as bus and rail transit, it can be observed that if the alternative transport mode is rail transit, households whose monthly income is 5,000-15,000 baht are more likely to enjoy time cost saving, which in turn will locate themselves on a more distant area. In contrast, household whose monthly income is greater than 15,000 baht can enjoy time cost saving advantages and tend to locate on farther area regardless of the alternative transit.

2.6 Summary

Previous studies showed the relationships between the urban rail transit development and its effects. Firstly, I found many substantial attempts have been empirically investigate among those relationships in developed countries but a few studies in developing countries.

Likewise, I also found a few researches of land development of Bangkok Metropolitan Region, especially in terms of land use conversions and residential location decision even if this fields have been recognized in other countries more than decades. Furthermore, Bangkok Metropolitan Region has implemented urban rail transit less than 15 years, that is, less investigation in urban rail transit studies. Fortunately, recent studies attempted to interpret land development in term of property value uplift due to urban rail transit investments. However, those studies only focused on the properties (e.g. office rent and condominium price) along the BTS Skytrain.

Thus, I intend to investigate the land conversions, land value uplift and residential location decision that are one of the directions in explaining land development due to the effect of urban rail transit development both existing and under construction network. However, not only the effects of urban rail transit development have been considered to land development, but also the characteristics of location and neighborhood and their attributes.

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CHAPTER 3

CHARACTERISTICS OF BANGKOK METROPOLITAN REGION

This chapter explains the background and characteristics of Bangkok Metropolis from the past until now. Further, it also reviews and describes the development policies of urban, suburban, and their transportation system. The transportation development contains road-based, rail-based, and water-based systems which are the main modes for get around in the city and its adjacent areas. However, rail-based development, in particular rail transit, gets the most attentive system since it has been stressed as the top priority projects. Therefore, understanding the impacts of railway transit development is necessary. To identify the extent of development impact consideration, the previous studies are summarized.

Bangkok Metropolitan Region, a capital city of Thailand, is selected as a case study for the empirical analysis. The Bangkok Metropolitan Region (BMR), also known as Greater Bangkok is the urban conglomeration of Bangkok, Thailand, consists of a large core so-called Bangkok Metropolitan Area (BMA) and the five vicinities of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon as shown in Figure 3 - 1. It covers an area of 7,761.50 km^2 and has an estimated population of 15.6 million in 2012 with a population density of 1,301.42 per km^2 (National Statistical Office, NSO).

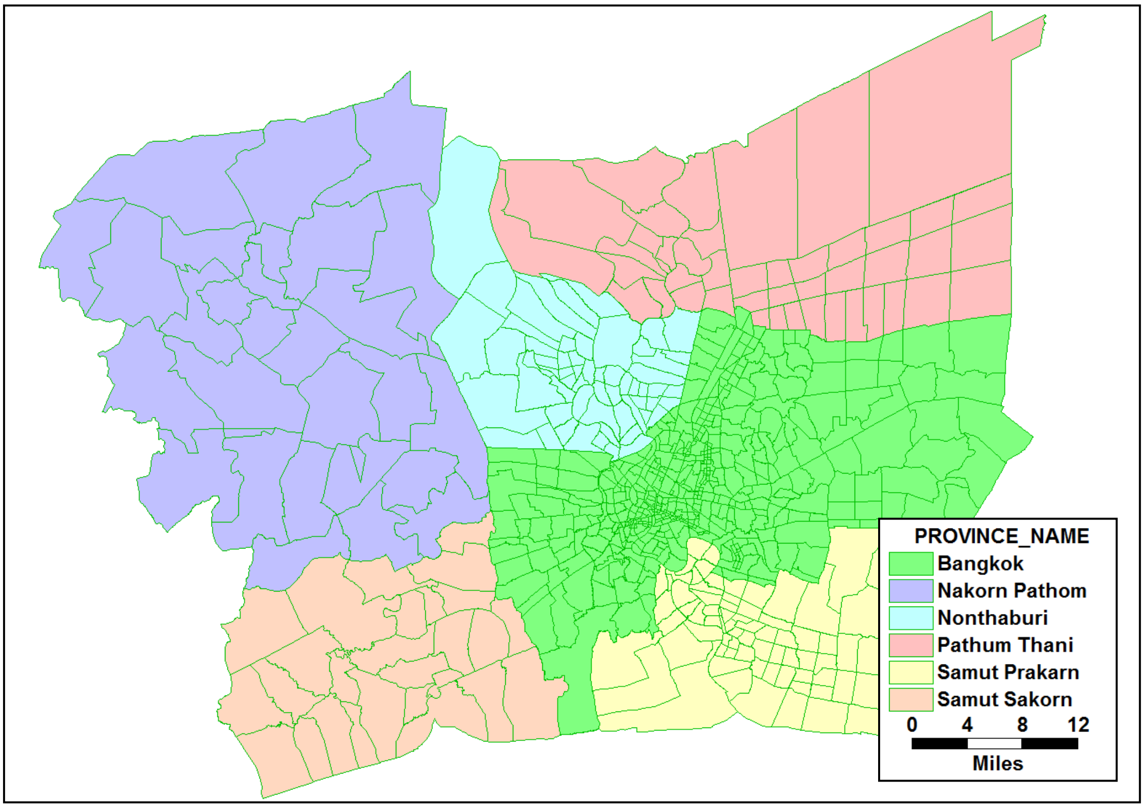

Figure 3 - 1 Boundary of Bangkok Metropolitan Region, Thailand
Source: Bangkok Metropolitan Administration, BMA

3.1 Urban Spatial Structure

In the early period, most people settled along the Chao Phraya River and the canals. Waterway served as the main mode of transportation for Bangkoknians' commuting. By the mid-19th century, the commuting system was changed from water transport to land transport. Chareon Krung Road, the city's first paved street was constructed in 1862. This was followed by Bamrung Mueang, Fueang Nakorn, Trong (now Rama 4) and Si Lom Roads and followed by these in the outer area of the city. Land transport had gradually surpassed the canals in importance. These made the residential community were uncontrolled expansion to north, south and east. Later, the first bridge, namely King Rama 4 Bridge, was constructed over Chao Phraya River. Then, Buddha Yodpha Culaloke Bridge or Memorial Bridge was built in 1932 to connect Thonburi and Bangkok. This development resulted in the urbanization expanded, economic and motorization increased and industrialization developed rapidly.

3.1.1 Urban Sprawl

Table 3 - 1 and Table 3 - 2 present the number of populations and annual growth rate in the Metropolitan Region of Bangkok (BMR) and the areas within the administrative boundaries of Bangkok (BMA) or so-called the Vicinity which consists of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon. Since 1960, the city had experienced population growth rapidly. The population has increased from 2.1 million in 1960 to 3.1, 4.7, 6.3 and 8.3 millions in 1970, 1980, 1990, 2000 and 2010, respectively as shown in Table 3 - 1 (National Statistical Office). Not only have the population in the BMA increased, but the Vicinity was. The Vicinity has faced the population growth from 1.2 million in 1960 to 6.3 million in 2010. In the other word, the population of the Vicinity grew 34.8 percent between 1960 and 1970 or at rate of 3.48 percent annually and 50.6 percent between 2000 and 2010 or at rate of 5.06 percent annually as shown in Table 3 - 2. Though Bangkok' population has increased rapidly, the annual growth rate has declined from 3.89 and 4.16 percent a year in the 1960s and 1970s to average 2.5 percent a year in the 1980s and 2000s and less than 1 percent annually in the 1990s. For the BMR, it notes that the population growth rate grows around 3 percent annually from the 1960s to 2000s.

Table 3 - 1 Number of Populations in Bangkok Metropolitan Region

		Number of Populations (1,000,000 Persons)					
		1960	1970	1980	1990	2000	2010
BMR		3.3	4.8	6.6	8.6	10.1	14.6
	BMA	2.1	3.1	4.7	5.9	6.3	8.3
	Vicinity	1.2	1.4	1.9	2.7	3.8	6.3

Source: National Statistical Office, NSO

Table 3 - 2 Annual Growth Rate in Bangkok Metropolitan Region

		Annual Growth Rate (%)				
		1960s	1970s	1980s	1990s	2000s
BMR		3.75	3.18	2.65	1.61	3.68
	BMA	3.89	4.16	2.27	0.66	2.75
	Vicinity	3.48	3.05	3.51	3.42	5.06

Source: National Statistical Office, NSO

The population growth rate of the BMA was not only mainly due to its natural growth, but also related to a huge number of migrations from other provinces or regions. Table 3 - 3 shows the net migration in each region of Thailand, namely the BMA, Central, Northern, Northeastern and Southern Region during the 1980 and 2000 as well as annual net migration rate in Table 3 - 3. Net migration tends to drive the BMA's population change in any given year from an increase of 230,000 residents in 1980 to a decline of 118,000 residents in 2000. Comparing the regions, the number of net migration was steadily highest in the Central Region around 12, 27 and 72 thousands persons in 1980, 1990 and

2000 respectively. The table also reveals that net migration has played a substantial role in the growth of the BMA as well as the Central region by evidently, the high rate of net in-migration in the BMA and Central region, while out-migration slowed down the overall growth rates of some regions such as the Northeastern in 1990 and 2000. Not only did rapid population growth occur in the BMA, but took place in the Vicinity and the rate was higher than that for the BMA (Lo and Yeung, 1996).

Table 3 - 3 Net Migration in each Region

	Net Migration (persons)		
	1980	**1990**	**2000**
BMA	230,072	431,767	118,102
Central	118,758	268,074	719,518
Northern	-109,851	-23,176	-55,265
Northeastern	48,274	-240,144	-352,156
Southern	32,804	-391,398	74,868

Source: National Statistical Office, NSO

The general result is that absolutely, or at least relatively, the city center that is urban core of the great agglomeration loses its significance as providers of living space compared with its suburbs. In the other word, it started the process of suburbanization. This may be the result of improvement in transportation infrastructures e.g. road network and bridge. Previous studies found the relationship between the transportation investments and the process of suburbanization accelerated. For instance, the introduction of road network into Boston likely caused the first major movement of people to suburbs during the 1850s and 1860s (Warner, 1962). Likewise, Taylor (1966) argued that the introduction of omnibuses, commuter railway and streetcars between 1830 and 1860 encouraged city-dwellers to live in outlying areas and travel to work. More recently, Baum-Snow (2007) showed that transportation improvements cause suburbanization. Furthermore, they found the evidence that the road network is commonly associated with urbanization and suburbanization (Kidokoro and Hanh, 1993) as illustrated in Figure 3 - 2. As indicated in the figure, it reveals that there is a strong correlation between the increasing of population and the location of artery roads.

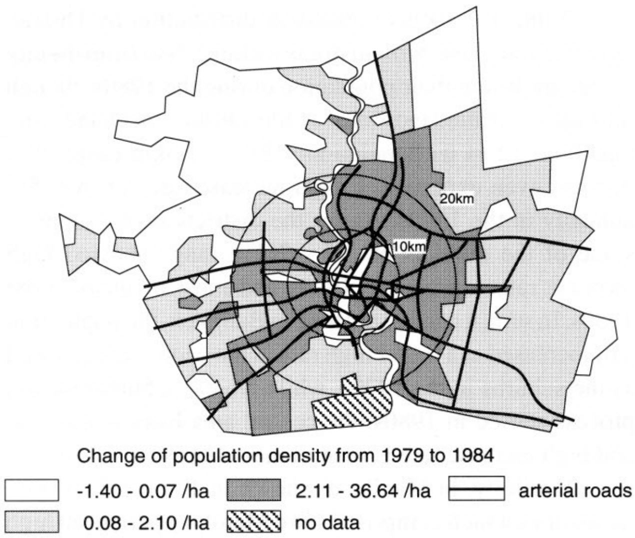

Figure 3 - 2 Change of Population Density along the Arterial Roads in Bangkok (1979-1984)

Source: Kidokoro and Hanh (1993)

In spite of this, population distribution, namely the pattern of urbanization, depends largely on the characteristics of road network when there is no strict land use control in Bangkok. Since the increase of population along artery roads in the suburbs is driven by motorization, severe traffic congestion around the gate-points is commonly seen, where a large amount of traffic originated in suburbs and is concentrated on a few trunk roads coming into the central area which is already saturated with traffic.

3.1.2 Economic Growth

Previous studies indicated the urbanization and suburbanization are inextricably linked with economic growth (Abdel-Rahman *et al.*, 2006; Harris, 1990; Henderson, 2003; Moomaw and Shatter, 1996; Quigley, 2008).

At first, much of the impressive economic growth recorded by Thailand was owned to the steady expansion of the agricultural sector. However, in 1955 Thailand begun to see a huge change and had experienced a high level of economic growth during 1985-1995with average economic growth of 10 percent per annum as shown Table 3 - 4 and Table 3 - 5 which was the result of the economy shifted from agriculture to industry. Nevertheless, the rapid economic growth was evenly distributed throughout the country, reflected by the BMA and the Vicinity was considered to be the highest share of GRP, posted at average 50 percent of the whole kingdom in 1985 and remained unchanged in 2010 and followed by the Eastern that accounting for only 15 percent of the national gross product (GNP) in 2010. In the other word, GRP of the BMR, which the highest rank, was up to 2-3 times higher than the second rank.

Noticeably, since 1997 Thailand had declared to float the national currency and this was usually marked as the beginning point of the Financial Crisis. The annual growth rate of GRP during the crisis (1995-2000) grew at 2.59 percent per annum for the BMR and 3.68 percent per annum for the whole kingdom. After the crisis, the annual rate, in turns, grows at 6-7 percent per annum.

Table 3 - 4 Number of Gross Regional Products at Current Market Prices

	Number of Gross Regional Product at Current Market Prices (GRP) (trillion baht)					
	1985	**1990**	**1995**	**2000**	**2005**	**2010**
BMR	0.49	1.15	2.24	2.55	3.62	4.77
BMA	0.38	0.88	1.60	1.79	2.55	3.14
Vicinity	0.11	0.27	0.64	0.76	1.07	1.63
Central	0.05	0.09	0.21	0.31	0.46	0.66
Eastern	0.09	0.18	0.50	0.67	1.12	1.63
Western	0.06	0.10	0.16	0.20	0.30	0.42
Northern	0.13	0.22	0.31	0.39	0.59	0.83
Northeastern	0.15	0.26	0.38	0.47	0.65	1.02
Southern	0.10	0.19	0.40	0.47	0.72	1.11
Kingdom	1.06	2.18	4.21	5.06	7.59	10.81

Source: National Statistical Office (NSO)
Office of the National Economic and Social Development Board (NESDB)

Table 3 - 5 Annual Growth of GRP

	Annual Growth of GRP (%)				
	1990	**1995**	**2000**	**2005**	**2010**
BMR	17.06	13.33	2.59	7.01	5.52
BMA	16.80	11.96	2.24	7.08	4.16
Vicinity	17.96	17.26	3.44	6.84	8.42
Central	11.76	16.95	7.79	7.89	7.22
Eastern	13.86	20.43	5.85	10.28	7.51
Western	10.22	9.40	4.46	8.11	6.73
Northern	10.52	6.86	4.59	8.28	6.83
Northeastern	11.00	7.59	4.25	6.48	9.01
Southern	12.84	14.89	3.23	8.53	8.66
Kingdom	14.42	13.16	3.68	8.11	7.07

Source: National Statistical Office (NSO)
Office of the National Economic and Social Development Board (NESDB)

Moreover, the BMR has the highest per capital income as shown in Table 3 - 6. In contrast, the Northeastern region has the lowest, though this region corresponds to about one-third of Thailand and the total population of its 19 provinces in 2000 was 20.1 million, equivalent to approximately 34 percent of Thailand's total population. In the other word, the annual per capita income in the BMR was ten times higher than in the northeastern region in 1995 and remains unchanged in 2010. Furthermore, the disparity between both regions contracted to still widen around 8 times during the economic crisis.

Table 3 - 6 Per Capita Income of Population

	Per Capita Income of Population (baht/year)					
	1985	**1990**	**1995**	**2000**	**2005**	**2010**
BMR	61,228	127,275	229,432	245,395	323,532	412,887
Central	17,606	31,455	73,964	105,383	154,819	218,088
Eastern	28,409	50,425	129,185	163,606	288,015	441,901
Western	18,958	29,948	47,102	56,134	80,584	105,129
Northern	12,724	20,350	27,438	33,096	49,264	68,015
Northeastern	8,194	13,606	18,866	21,980	29,345	44,516
Southern	14,804	26,058	51,564	57,228	81,841	118,184
Kingdom	20,484	39,104	70,884	81,304	116,535	160,556

Source: National Statistical Office (NSO)
Office of the National Economic and Social Development Board (NESDB)

As the above results stated, it can be pointed that the major activities of the country is located in the Bangkok Metropolitan Area and the Vicinity. As a result of this situation, the per capita of the people in the BMR continue to be higher than those of other regions. Such high income enables them to buy goods and services as well as housing investments might attractive the people in other regions in-migrant to the BMR. As seen in several studies (Ha *et al.*, 2009; Li and Piachaud, 2004; Park and Wang, 2010; Wouterse, 2008), pointed that the dissatisfaction with widespread inequality and poverty encourages and accelerates the in-migration to the cities. With this a high rate of in-migration to the cities, it absolutely effects on the rapid growth of labor force and the employment structure.

3.1.3 Employment Structure

Thailand has, for a long time, has been known as a major agricultural country. During a half of century, there has been substantial diversification in agricultural production. Despite the increase in agricultural production, its importance in terms of share of national output has been declining sharply. In 1947, output of the agricultural sector constituted 60.3 percent of the total gross domestic product (GDP). The share was reduced to 26.2 and 10.9 percent in 1980 and 2010 respectively as shown in Table 3 - 7. Employment share, on the other hand, has been declining at much slower pace. In 1974, the share of economically active workers in the agricultural sector was 84.8 percent of total employment. It dropped to 82.3, 79.3, 72.5 and 62.9 percent in 1960, 1970, 1980 and 1990 respectively while the absolute number of GDP and people engaged in the agricultural sector, on the contrary, has been increasing over time. In 2000 and 2010, the agricultural share of employment remained less than a half of total employment distribution around 44.2 and 38.2 percent respectively. These results because workers migrated from agricultural sector to non-agricultural sector, e.g., manufacturing and commercials and services sectors. Manufacturing share of GDP increased from 10.8 percent in 1947 to 27.5 and 40.1 percent in 1980 and 2010 respectively. Also, the percentage of employment distribution in manufacturing sector increased from only 2.3 percent in 1947 to 20.6 percent in 2010. Furthermore, the commercials and services sector had become the largest share of production and employment. The GDP increased from 29.0 percent with share of employment 12.9 percent in 1947 to 43.0 percent with share of 37.2 percent in 2010.

Obviously, the employment structure shifted from agricultural sector to non-agricultural sector during the 1990 to 2000. The number jumped from 76.1 and 37.1 percent of GDP and employment share in non-agricultural sector to 91.5 and 55.8 percent. This might be the reflected of with 73 percent of the active population producing only 26 percent of the national output, the average income of workers in agricultural sector is undoubtedly be lower around 4 times than in the rest of the economy as presented in Table 3 - 8. This poverty has certainly been a dominant factor in pushing people out of agricultural areas to Bangkok and the Vicinity.

Table 3 - 7 Percentage Distribution of Production and Employment by Industry

Sector	1947		1960		1970		1980		1990		2000		2010	
	GDP	Emp	GDP	Emp	GDP	Emp	GDP	Emp	GDP	Emp	GDP	Emp	GDP	Emp
Agricultural	60.3	84.8	39.8	82.3	28.3	79.3	26.2	72.5	23.9	62.9	8.5	44.2	10.9	38.2
Non- Agricultural	39.7	15.2	60.2	17.7	71.7	20.7	73.8	27.5	76.1	37.1	91.5	55.8	89.1	61.8
Manufacturing	10.8	2.3	18.2	4.2	25.3	5.8	27.5	7.7	33.3	14.4	36.9	20.0	40.1	20.6
Commercials and Services	29.0	12.9	34.2	11.7	39.7	14.0	41.0	17.1	40.1	22.6	48.7	32.1	43.0	37.2
Others	-	-	7.5	1.8	6.7	0.9	5.4	2.7	2.7	0.1	5.9	3.7	6.0	4.0
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: National Statistical Office (NSO)
Office of the National Economic and Social Development Board (NESDB)
Bank of Thailand and Labor Force Survey
Nitungkorn (1985) and Aemkulwat (2010)

For the employment structure in Bangkok and the Vicinity, over two decades, the services sector has played the most crucial role in Bangkok. In 2000, almost 30 percent of the employed workers in Bangkok engaged in service sector, of which the proportion has increased from 1980 as shown in

Table 3 - 9. Trade and commercial sectors are also major sources of employment in Bangkok, accounting for 23 percent of employed workers.

Table 3 - 8 Monthly Wage Rate by Industry

Sector	BMA			Whole Kingdom		
	2000	2005	2010	2000	2005	2010
Agricultural	-	3,907	11,223	2,381	2,866	4,245
Non-Agricultural	-	12,294	15,844	7,522	8,226	10,069

Source: National Statistical Office (NSO)
Office of the National Economic and Social Development Board (NESDB)
Bank of Thailand and Labor Force Survey

Table 3 - 9 Percentage Distribution of Employed Workers in 1990 and 2000

	BMA		Vicinity		BMR	
	1980	2000	1980	2000	1980	2000
Industry	21.2	17.9	20.7	31.4	21.0	23.3
Commercial	22.3	23.3	10.5	16.7	18.5	20.7
Banking	3.4	7.2	0.8	3.0	2.6	5.5
Services	27.7	28.6	12.0	19.3	22.7	24.9
Others	18.6	12.7	5.0	24.4	28.7	17.4
Total	**93.2**	**89.7**	**94.1**	**94.8**	**93.5**	**91.8**

Source: National Statistical Office (NSO)
Choiejit (2002)

Employment structure in Bangkok and the Vicinity varies greatly across its areas. For the inner area of Bangkok, commercial, financial and service sectors account for more than 50 percent of all employment in this area. Employment in commercial and financial sector in the inner zone increased from 34.4 percent and 20.3 percent in 1990 to 35.9 percent and 23.5 percent in 2000 as presented in Table 3 - 10.

Table 3 - 10 Percentage Distribution of Employment in Bangkok and the Vicinity

	Inner		Urban Fringe		Outer		BMA		Vicinity	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
Manufacturing	17.7	15.9	39.9	30.2	66.7	48.7	40.5	33.9	86.5	80.3
Commercial	34.4	35.9	22.3	28.5	12.0	17.9	23.3	26.2	4.1	6.6
Financial	20.3	23.5	10.1	13.1	3.6	8.2	11.6	13.9	0.8	2.4
Services	7.8	7.0	9.5	8.6	6.7	6.6	8.0	7.4	2.0	2.3
Others	19.8	17.7	18.3	19.5	11.1	18.5	16.6	18.7	6.7	8.4

Source: Department of Labor Protection and Social Welfare
Choiejit (2002)

Let notice the table, the inner area of Bangkok was occupied by trade and commercial establishment and office building especially financing and banking as well as government offices. The manufacturing sector, on the other hand, was located in the urban fringe, outer area and the Vicinity as well. However, there was relatively less significant for the inner area of Bangkok. Furthermore, the proportion in trade and commercial sector in inner area increased slower from 34.4 percent in 1990 to 35.9 percent than 22.3 percent to 28.5 percent in the urban fringe area.

For the outer area, the major source of employment is the manufacturing sector though this has continued to decline as seen in the inner area. The proportion of employed workers in manufacturing sector dropped from 67 percent in 1990 to 49 percent in 2000. Whereas the employment in commercial, business, and others have increased their roles in the outer area to accord the expansion of the city from the city center to the outskirts. For the Vicinity, the manufacturing sector is still the major source of employment, with over 80 percent of all employment in 2000 accounted for by the manufacturing sector although the proportion had somewhat decreased from 87 percent in 1990.

For the employment locations in the Bangkok and the Vicinity, they are largely concentrated in the inner area as shown in Figure 3 - 3. Such an urban structure brings a huge amount of travel demand and increases commuting distance. Therefore, it is hardly to keep away from the traveling by private car in order to reduce the travel time. This may be cause and consequence of the critical of traffic congestion on many roads head to inner area.

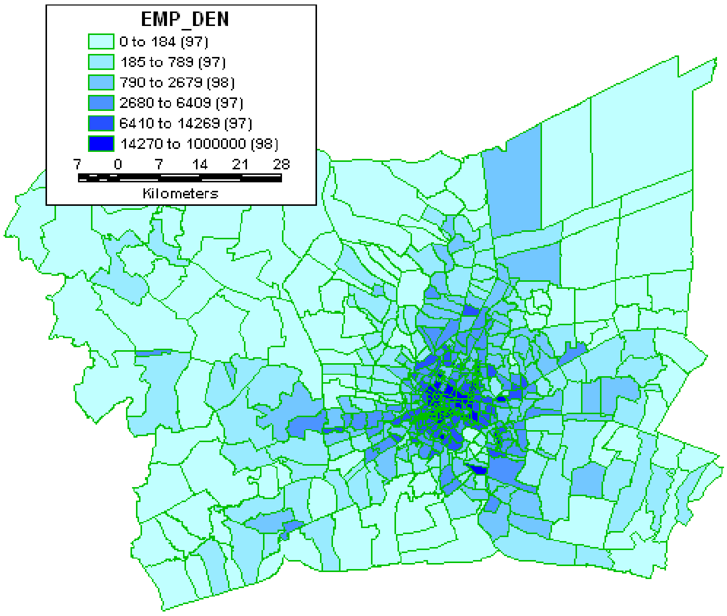

Figure 3 - 3 Employment Concentrations in 2005
Source: Management of Road Traffic

3.1.4 Land Uses Pattern

Table 3 - 11 showed that the land converted to urban use was increase from 302 km^2 in 1987 to 614 km^2 in 1995, a double increase during the period 1987-1995. The land converted to urban use in the outer zone of Bangkok was faster than the inner and the middle zones of Bangkok. The expansion of Bangkok was unplanned by which land use was uncontrolled. Such a rapid growth was due to the expansion of population settlement and economic activities in a horizontal manner to the outer areas and the vicinity of Bangkok causing degradation of agricultural areas. The expansion of the city occurred along the communication lines connecting Bangkok to surrounding provinces and other regions particularly along the edge of the commuting lines, making super block to the land inside to be reached and developed. This has made such expansion of Bangkok city cover larger area than expected. Besides, those who live in the superb area have on average longer distances to travel to

enter the city and thus the government needs to carry much more burden in communication and transportation investment. Moreover, using personal cars were encouraged to save traveling time.

Table 3 - 11 Bangkok's Land Converted to Urban Use

Areas	Total Area (km^2)	Land Converted to Urban Use (km^2)		
		1987	1993	1995
Inner	59.5	44.1	44.8	44.9
Urban Fringe	165.1	96.9	115.7	116.6
Outer	1,344.1	161.3	339.2	452.1
BMA	1,568.7	302.3	499.7	613.6

Source: Department of City Planning, BMA, 1999
Choiejit (2002)

3.2 Transportation System

3.2.1 Commuting Modes

Main commuting modes in Bangkok Metropolitan are classified into three groups: private modes (e.g. car, pick-up, and motorcycle), public modes (e.g. bus, boat, van-taxi, and MC-taxi) and non-motorized modes (e.g. waking and cycling). Among these modes, it was estimated there were about 19.44 million linked person trips made each day in the BMR with 46% by private modes, 40% by public modes (3% of MRT and 37% of bus and other public transport) and 14% by non-motorized modes in 2005 (World Bank, 2007).

3.2.1.1 Private Modes

Earlier, it was observed that the car ownership in Bangkok was a requirement only for people with high incomes as an indication of power and social status (Morikawa et al., 2001). They found the relationship between household income and the vehicle ownership by car ownership is increasing with increasing income and motorcycle ownership is higher than car ownership for low income households as shown in Figure 3 - 4 (Urban Transport Database and Model Development Project, Final Report, 1998). Additionally, owning two or more car is very low even with high income households indicating the difficulty of affording multiple cars.

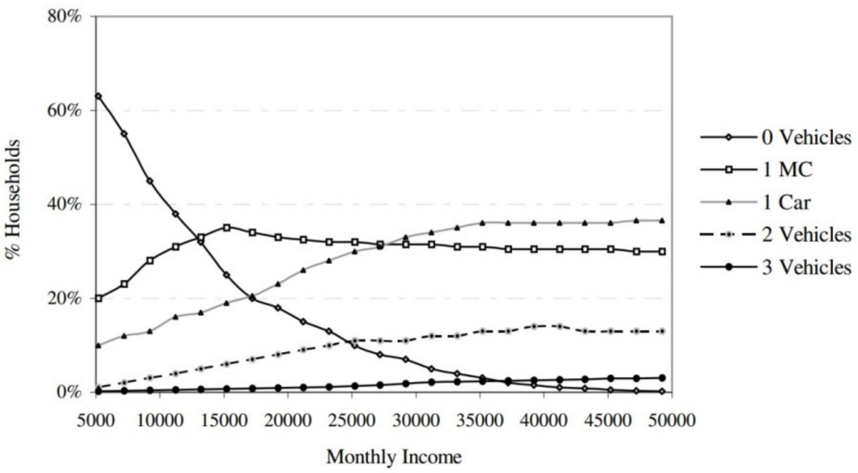

Figure 3 - 4 Household Distribution by Income and Vehicle Ownership in Bangkok in 1995/1996
Source: Urban Transport Database and Model Development Project, Final Report, 1998

But finally, owning car has become more important aspect for people (if they can afford) so as to manage their mobility because of the inefficient level of service offered by public transport.

According to the Department of Land Transport Statistics, the number of vehicle registration in Bangkok was about 2.1 million in 1990 and increased rapidly to 4.90 and 6.44 million in 2005 and 2010 respectively as shown in Table 3 - 12. For the BMA, the number of motorcycle was quite equivalent to the number of car during 1990 and 2000 respectively and gradually became less than in 2005 and 2010. In contrast, in a whole kingdom the number of motorcycle was steadily much higher. Moreover, Bangkok accounts for about 20-30% of the nation's registered motor vehicles including 35-50% of the private car fleet (car, pick-up and vans) and 15% of private motorcycles. Over the period from 1990 to 2010, an average private car rate was about 6.5% per annum, thus increasing by sixth over this period. While the number of motorcycles registered grew at 5% per annum over this period.

Table 3 - 12 Number of Vehicles

	Number of Vehicles (1,000,000 vehicles)				
	1990	**1995**	**2000**	**2005**	**2010**
Kingdom	7.11	13.84	20.03	21.73	27.53
Car	1.70	3.31	5.32	6.57	8.99
Motorcycle	4.78	9.31	13.82	14.55	17.16
BMA	2.05	3.24	4.50	4.90	6.44
Car	0.87	1.34	1.98	2.53	3.37
Motorcycle	0.73	1.37	1.96	1.92	2.50

Source: Department of Land Transport (DLT)

Table 3 - 13 Average Growth Rate during 1995 and 2010

	Average Growth Rate (%)			
	1995	**2000**	**2005**	**2010**
Kingdom	13.32	7.39	1.62	4.73
Car	13.33	9.49	4.22	6.27
Motorcycle	13.33	7.90	1.03	3.30
BMA	9.15	6.57	1.70	5.47
Car	8.64	7.81	4.90	5.73
Motorcycle	12.59	7.16	-0.41	5.28

Source: Department of Land Transport (DLT)

3.2.1.2 Public Modes

Public modes in Bangkok and the Vicinity are quite mixed and chaotic as other developing countries. The main modes of public transport are land transport system (e.g. bus, van-taxi, MC-taxi, and so on) and water transport system (e.g. express boat along the river and canal).

Urban bus services were authorized by Bangkok Mass Transit Authority (BMTA). The government considers BMTA services as a welfare function. Therefore, BMTA services are providing cheap fare for lower income groups. Early, most regular bus services are operated by that organization. Later, privates' joint buses also operate under concession to provide supplementary services. Generally, the buses are divided into two group; regular bus without air conditioning and air conditioned bus. However, poor, unreliable, unpunctuality and unsafe services are commonly noticed in the BMR. These have directly or indirectly forced commuters to shift to a more convenient mode of transport or private car (Tanaboriboon, 1993).

Since the 1997 financial crisis, there has been growth in the use of 10-12 seats air-conditioned vans or so-called van-bus which provides more convenient and faster, while, the fare is quite similar to buses. At first, drivers developed their services from school bus operations during their free time for point-to-point commuter services (Leopairojana and Hanaoka, 2005). Gradually, these services were adapted from provincial passenger vans operated between Bangkok and adjacent areas (Eamsupawat, 1999). Though, original van bus services were illegal. In 1999, the regulating of these services was approved from BMTA.

Another main mode of public transport can be found in the BMR and also as in common with other countries is taxi. However, the fare charged for riding taxi is much higher compared with the urban bus service and van-taxi.

Table 3 - 14 present the number of van-bus and taxi operated in the BMR during the year 2000 and 2010. The number of taxi grew at 4.03% per annum over this period, while the number of van-bus grew at the relatively faster rate of 15% per annum. In contrast, the numbers of urban buses remain unchanged (BMTA). From this evidence, it can be said that public attitudes toward the bus system are not highly favorable. In the other, they do not appreciate the services being offered. Thus, van-bus and taxi are more likely to commute than urban bus.

Table 3 - 14 Number of Van-bus and Taxi with Average Growth Rate

	Number of Van-bus and Taxi (vehicles)			Average Growth rate
	2000	2005	2010	2000-2010 (%)
Van-bus	1,295	5,519	5,797	14.99
Taxi	64,321	77,836	96,255	4.03

Source: Department of Land Transport (DLT)

In addition, various and the unique feeder modes or so called paratransit are found in the BMR, locally known as motorcycle-taxi, songtaew (a converted pick-up truck), silor-lek (a small 4-wheel car), and tuk-tuk. These modes are also available to Bangkok commuters especially those who live in dead-end, narrow streets or local streets (so-called soi) where other forms of public transport are not available. These paratrasnit modes usually provide a loop-type of service and operate on a flexible schedule depending on the passengers' demand. They travel on fixed-route (except motorcycle-taxi and the fare charge is much higher than other modes) but no fixed-stop, so passengers can board and alight anywhere they want along the route.

According to the geographical location of the BMR, the waterway networks provide possible accessibility through their tributaries. This make Bangkokians have option to travel by boat services. Currently, there are three major routes for boat services: along Chao Phra Ya River, Saen Sab and Phra Kanong Canal. Though water transport plays a less important role that land transport system due to its confined services areas, it is alternative means of transport for reduce travel time during peak hours because of the lower traffic congestion in waterway transportation routes.

3.2.1.3 Non-Motorized Modes

Non-motorized transport modes such as walking and cycling are environmentally friendly, cheap, reasonably fast alternatives for short trips (sometimes for long trips when in traffic congestion) and good for health. However, walking and cycling in the BMR got 14% of all daily trips which was less than half the Asian city average of 32%) and the proportion of workers use walking and cycling for the journey to work in the BMR was very low with 10% while European and other Asian countries have 21% and 25% respectively (Kenworthy,1997). This result is relatively poor facilities: the narrowness of sidewalks, many obstructions to pedestrians on sidewalks, damage sidewalks and unavailability of suitable facility for cycling (e.g. bicycle lanes).

3.2.2 Mass Transit System

Recently, the urban rail transit has been introduced to alleviate the traffic issues. Later in 1999, the first 23.5 kilometers mass transit the holding enterprise of the Bangkok Metropolitan Administration (BMA), namely Bangkok Mass Transit System (BTS skytrain), has been serviced with two initial green lines, Sukhumvit line and Silom line. Between two green lines are able to transfer at Siam Square station. Early, the Sukhumvit line was running 17 kilometers from Mo Chit station to On Nut station. In August 2011, 5.25 kilometers was extended from On Nut station to Bearing station. While, the Silom line was running 6.5 kilometers from National Stadium station to Saphan Taksin station. In August 2009, 2.2 kilometers was extended from Saphan Taksin station to Wongwian Yai station (Bangkok Mass Transit System Public Company Limited). Five years later after BTS first opened, a 20 kilometers Bangkok Mass Rapid Transit (Chaloem Ratchamongkhon line or MRT blue line) was launched at underground level from Bang Sue station to Hua Lamphong station in July 2004 (Mass Rapid Transit Authority of Thailand, MRTA). Six years later after MRT opened, a 28.5 kilometers Suvarnabhumi Aiport Rail Link, as known an Airport link, has opened in August 2010 from Phaya Thai station to Suvarnabhumi Airport station. This line provides transportation service for passengers who wish to travel from inner city to the airport with more convenient, faster, and more flexible with two choices of service systems consist of SA Express and SA City line (State Railway of Thailand). SA Express provides service from Makkasan satation to Suvarnabhumi Airport station which stops only at original and end terminal, meanwhile, SA City line provides service from Phaya Thai station to the end terminal at Suvarnabhumi Airport which stops every stations. Among of them are five transfer stations that is no track connection, namely Asok, Mo Chit, Sala Daeng, Phaya Thai, and Phetchaburi. Nowsadays travel by rail transit in Bangkok has increasingly obtained interest due to its safe, punctual, as well as convenient service.

Although there are only three lines are currently in operation, the new urban rail transit lines consist of a 15-kilometer SRT Light Red line, a 23-kilometer MRT Purple line and a 27-kilometer extension of MRT Blue line are now constructed in January 2009, November 2009 and June 2011, respectively. Moreover, a 12.8-kilometer of the extension of BTS line, from Bearing Station to Sumut Prakan Station, was built in 2012.

Not only was the urban rail transit system implemented in Bangkok, a high capacity, faster and more efficient bus, as known a Bus Rapid Transit (BRT) was declared in 2004. Then, construction on the first route began in 2007, namely BRT Sathorn and Ratchapruk. The route, opened for trial runs on 29 May 2010 and officially opened on 14 February 2011, has begun running from Chong Nonsi BTS station to the Ratchada-Ratchapruk intersection in Thonburi district. The 16.5 kilometers route comprised of 12 stations in the southern core of Bangkok, characterized by a mixed high density land use among residential, commercial and employment areas. The system's island platforms are accessed by elevated enclosed station facilities, and it shares the ticketing system of the BTS skytrain. The buses run on dedicated bus lanes, which were criticized by motorists during the beginning of the system's trial run for worsening traffic congestion.

The existing, under construction urban rail transit network and bus rapid transit route are shown in Figure 3 - 5.

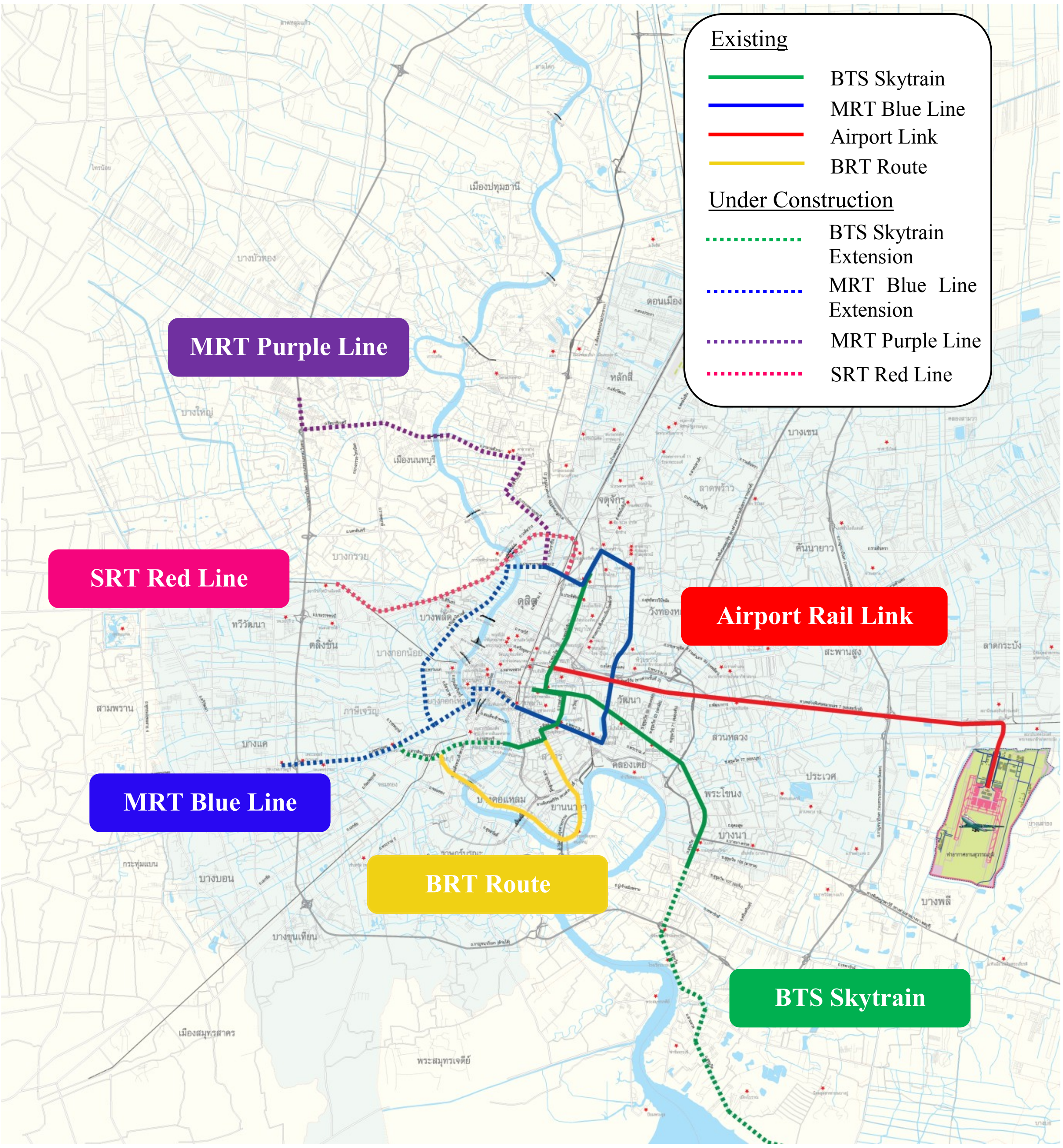

Figure 3 - 5 Map of Bangkok Metropolitan Region (BMR), Existing and Extension Urban Rail Transit Network and Bus Rapid Transit Route

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CHAPTER 4

WHETHER URBAN RAIL TRANIST DEVELOPMENT INDUCE LAND USE CHANGE

The purpose of this dissertation intends to examine the effects of urban rail transit both existing network and extension in three principal ways. One of them was presented in this chapter which aims to track and observe the conversions of land along the existing and under construction urban rail transit corridors in Bangkok Metropolitan Region. Specifically, investigate whether urban rail transit development and changes in land use are closely related or not and how. In order to see the effects of urban rail transit development on land use conversions, satellite images covering an area within an observable corridor of 5 kilometers are employed by tracking each land parcel at the same address but different years between 2004 and 2010. Each of land parcels is aggregated into four categories: undeveloped land (agricultural land or no buildings), residential land (detached house, semi-detached house, attached house, and row house), high-rise residential land (condominium and apartment) and non-residential land (commercial and industrial). These categories simplify the conversion analysis. An application of discrete choice model, namely multinomial logit model, is applied to investigate whether urban rail transit investment alter the urban form. This will be valuable information in which types of land use conversions are most profitable with respect to distance from the stations and other variables including local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute.

4.1 Background and Motivation

The effects of transportation investments on urban development are perhaps one of the most important and contested, concerns in urban and transportation planning. In particular, it has long been known that transportation investments such as urban rail transit will generate effects by making adjacent area of that corridor relatively more accessible. Thus, it will contribute to increase densities and change the urban form because that potentially attracts land developers. However, it has until recently routinely ignored that effects, and the consequence indirect effects that such induced development can have on efficacy of alternative transportation investment strategies.

Many previous studies in developed countries (Carrión-Flores and Irwin, 2004; Dueker and Bianco, 1988; Funderburg *et al.*, 2010; Giuliano, 1989; Giuliano, 2004; Huang, 1996; Hurst, 2011; Knight, 1980; Knight and Trygg, 1977; Landis *et al.*, 1995; Muller, 2004; Nelson *et al.*, 2004; Vessali, 1996) and a few in developing countries (Cervero and Kang, 2011; Serneels and Lambin, 2001; Weng, 2002; Yang *et al.*, 2008) have discussed the connection between land use and transportation development. However, Bangkok Metropolitan Region is still young to its urban rail transit history. Therefore, this chapter hypothesizes that urban rail transit investment induced land use change, i.e., the investment in urban rail transit is an incentive the residents and businesses to move to areas with its service. In the other word, this chapter proposes to investigate the extent of the influence of transportation improvement, in particular urban rail transit system on land development, i.e., land use changes occurring from 2004 to 2010.

Such understanding the effects is necessary for integrating the impacts of transportation system development especially urban rail transit system into the transportation and urban planning policy in order to ensures adequate provision of public and private services in accompany with policies, it is important to anticipate changes.

4.2 Objective and Approach

The main objective of this chapter aims to investigate the conversions of land due to the effect of urban rail transit development in Bangkok Metropolitan Region. I hypothesize that urban rail transit development make an adjacent area relatively more accessible that attract the developers which, in turn, contribute to change the urban form.

To fulfill the objective of this chapter, the overall process is to be followed as below.

- First step observes land use change between the years 2004 and 2010 regarding to four categories: undeveloped land (agricultural land or no buildings), residential land (detached house, semi-detached house, attached house, and row house), high-rise residential land (condominium and apartment) and non-residential land (commercial and industrial). Then, comparing at the same place so as to indentify the land use conversions. Specifically, satellite image in the given area was divided into rows and columns, which form a regular grid structure of equal size. Each grid cell, 20 x 20 meters, was regarded as a point in the area. In addition, one land parcels changed, perhaps, composes of many grid cells.

- Second step examines the influencing factors in determining the changes of land use using an application of discrete choice model, namely multinomial logit model

- Third step considers the role of urban rail transit in term of benefits of urban rail transit development.

The rest of this chapter is organized as follows. The next section explains data collection and variable specifications. Then, the descriptive statistics in order to explain the differences of changes and other factors among land use pattern groups will be presented. Next, discrete choice model are applied to estimate the changes in land use impacts of urban rail transit development.

4.3 Data Collection

The areas within 5 kilometers from the representatives of urban rail transit station were chosen to observe the effect of distance to those stations. Specifically, thirteen stations of the BTS Skytrain, eleven stations of MRT Blue Line, five stations of Airport Rail Link, and nine stations of MRT Purple Line were selected to demonstrate the effects of urban rail transit investment on localized land use change. Although four urban rail transit lines were chosen to present the effects of urban rail transit development on land use change, the conversions due to the BTS Skytrain and MRT Blue Line development effects were grouped together because of the time periods of started their services and investigation (satellite image between 2004 and 2010). Thus, the study areas along the urban rail transit corridors are presented in Figure 4 - 1 to Figure 4 - 3 Three criteria are used to select these stations. The first was data availability, it is essential that historical information on station area land uses be available. The second was change: it is necessary to be able to observe land use change at or near the stations during the study period. A third criterion was that the selected stations be broadly representative of all stations in each line.

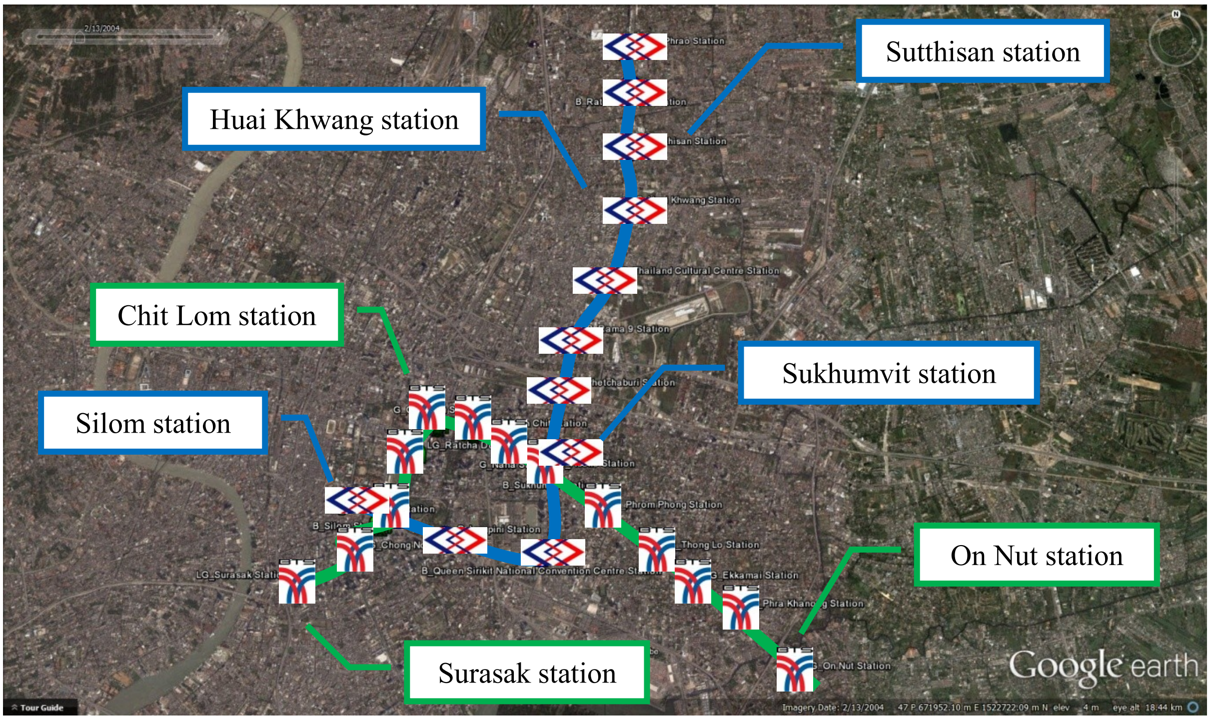

Figure 4 - 1 Representative Stations of BTS Skytrain and MRT Blue Line

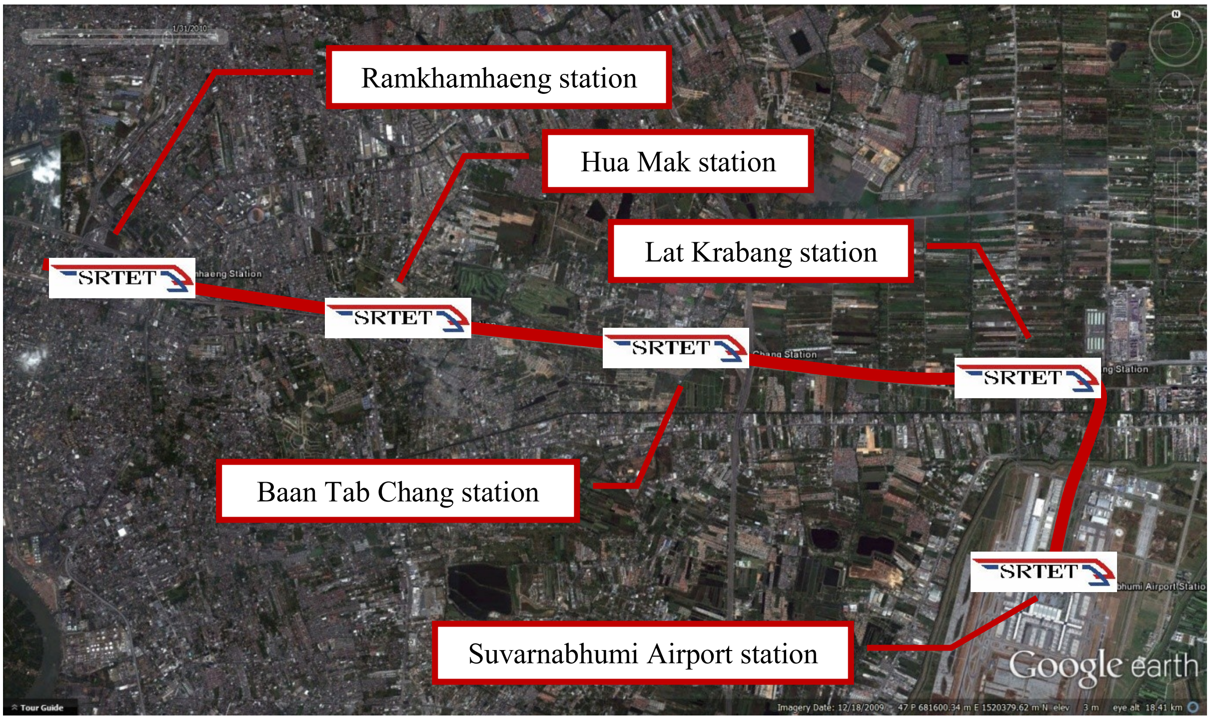

Figure 4 - 2 Representative Stations of Airport Rail Link

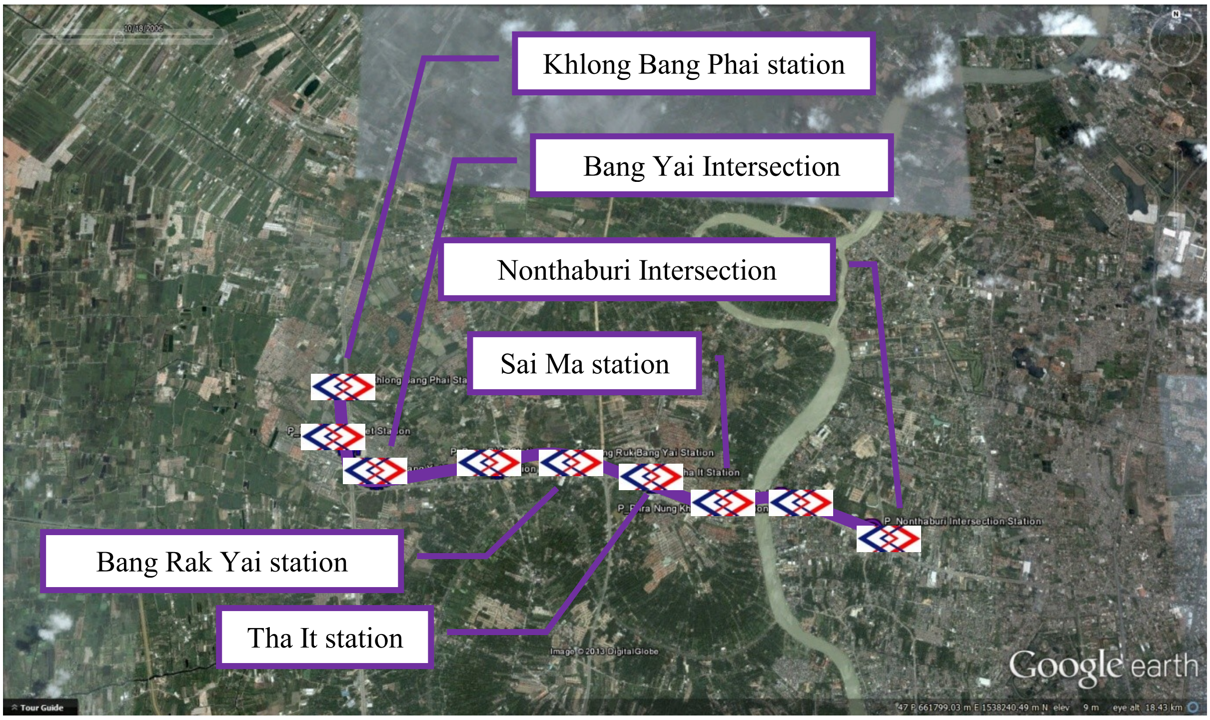

Figure 4 - 3 Representative Stations of MRT Purple Line

The analysis criterion is different depending on time periods as shown in Table 4 - 1. First criterion is for BTS Skytrain and MRT Blue Line stations which the system was the after full system operation until present (2004-2010). Second criterion is for Airport Rail Link stations which the system was before construction (2006-2009) and after the first years of operation (2010). Third criterion is for MRT Purple Line stations which the system was before construction and during the construction.

Table 4 - 1 Time Periods of Urban Rail Transit Constructions

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014

(green)	During BTS Skytrain construction (1992-December 1999)
(blue)	During MRT Blue Line construction (1999-July 2004)
(red)	During Airport Rail Link construction (2006-December 2009)
(purple)	During MRT Purple Line construction (2009-2014 expected)

In order to observe the change of land use, each land parcel was aggregated into four categories: undeveloped land (agricultural land or no buildings), residential land (detached house, semi-detached house, twin house, and townhouse), high-rise residential land (condominium and apartment) and non-residential land (commercial and industrial). Satellite image was employed to derive land use information in the year 2004 and 2010. The satellite image used for investigating come from Digital Globe which they cover all of the study areas. For each year, the satellite image was divided into rows and columns, which form a regular grid structure of equal size. In addition, one land parcel, perhaps, composes of many grid cells. The general rule is to decrease the grid sizes as much as possible to get the finest resolution. Each grid cell is regarded as a point in the area and indexed as one of above four categories.

After indexed the conversion of each grid cell, three land use change models will be generated regarding areas along the urban rail transit corridor including land whose use changed will be converted in the areas along the BTS Skytrain and MRT Blue Line, Airport Rail Link as well as MRT Purple Line. Finally, to capture the effect of urban rail transit on land use change, the likelihood of the conversions of land use will be compared among the three urban rail transit lines.

4.4 Variable Specifications

Four types of information used as explanatory variables: local transportation accessibility, work and non-work accessibility, neighborhood amenity as well as land attribute are summarized in Table 4 - 2.

Local transportation accessibility variable refers to the proximity to transportation including urban rail transit station, main road and expressway entrance access. As pointed out in previous studies, the demand for properties should be greatest near transportation system, thus, the proximity to the urban rail transit station, main road and expressway facilities are used to capture the potential of local transportation accessibility on the conversions of land. The proxy was computed using the Geographic Information System (GIS) tools from every parcel to rail transit stations, main roads and expressway entrance ramps as the straight line distance and then the shortest distance was selected. Furthermore, the proximity to urban rail transit station variable was also measured by distance intervals in order to capture the conversions at each band. For example, DIST_BBSTA0.4 means the value is set to 1 if land parcels being located within 400 meters from BTS Skytrain and MRT Blue Line station, and set to 0 otherwise.

Work and non-work accessibility refers to distance to the CBD and shopping mall. In the classical urban economic treatment of land use, work location and shopping center are all assumed to be located in the same place. In the current context of Bangkok Metropolitan Region structure, there is functional differentiation among areas with cluster of shopping centers, job centers and other facilities separated from each other. However, the largest work employment still in the central business district (CBD). Thus, I measured access only to CBD by the straight line distance as the work accessibility. Furthermore, the proxy to CBD also represents as the city center. As a difficulty to identify the boundary of the CBD, hence, Siam Square area was assigned to be the CBD of Bangkok Metropolis. On the other hand, short distance to the closest shopping mall is an indication of non-work accessibility. In addition, the shopping center in this study means a building forming a complex of shops, recreations, amusements, etc. The expectation of these measures, that is, the probability of converting parcels increases as the distance to CBD and shopping center decreases.

For neighborhood amenity, numerous literatures have confirmed the significance of neighborhood characteristics in determining land and housing prices. As such they are contributors to land use changes as well, since land use in turn influenced by land prices. In addition, neighborhood amenity indicates how attractive the site would be for residential and non-residential development, as well as the price that developers need to pay for land for residential and non-residential development in this neighborhood. These variables include the median income and density of each zone (e.g. household per square kilometer, employment per square kilometer as well as student per square kilometer). The actual record of neighborhood data collected by National Statistical Office, was obtained from the transportation model of Bangkok Metropolitan Region as known as e-BUM which is the district's database of Bangkok Metropolitan Region in the GIS program, therefore it can indicate each parcel's location into the GIS and identify the neighborhood amenity.

Table 4 - 2 Variables Description and Data Sources for Land Use Change

Variables	Description	Data Source
Local transportation accessibility		
DIST_STA	Distance to nearest station (km)	Calculated using GIS
DIST_BBSTA0.4	Dummy variable (set 1, if distance to BTS Skytrain and MRT Blue Linn ≤ 0.4km, otherwise 0)	Calculated using GIS
DIST_BBSTA0.8	Dummy variable (set 1, if 0.4km < distance to BTS Skytrain and MRT Blue Line ≤ 0.8km, otherwise 0)	Calculated using GIS
DIST_BBSTA1.2	Dummy variable (set 1, if 0.8km < distance to BTS Skytrain and MRT Blue Line ≤ 1.2km, otherwise 0)	Calculated using GIS
DIST_BBSTA1.6	Dummy variable (set 1, if 1.2km < distance to BTS Skytrain and MRT Blue Line ≤ 1.6km, otherwise 0)	Calculated using GIS
DIST_BBSTA2.0	Dummy variable (set 1, if 1.6km < distance to BTS Skytrain and MRT Blue Line ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_ASTA0.5	Dummy variable (set 1, if distance to Airport Rail Link ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_ASTA1.0	Dummy variable (set 1, if 0.5km < distance to Airport Rail Link ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_ASTA1.5	Dummy variable (set 1, if 1.0km < distance to Airport Rail Link ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_ASTA2.0	Dummy variable (set 1, if 1.5km < distance to Airport Rail Link ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_ASTA2.5	Dummy variable (set 1, if 2.0km < distance to Airport Rail Link ≤ 2.5km, otherwise 0)	Calculated using GIS
DIST_ASTA3.0	Dummy variable (set 1, if 2.5km < distance to Airport Rail Link ≤ 3.0km, otherwise 0)	Calculated using GIS
DIST_PSTA0.25	Dummy variable (set 1, if distance to MRT Purple Line ≤ 0.25km, otherwise 0)	Calculated using GIS
DIST_PSTA0.5	Dummy variable (set 1, if 0.25km < distance to MRT Purple Line ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_PSTA0.75	Dummy variable (set 1, if 0.5km < distance to MRT Purple Line ≤ 0.75km, otherwise 0)	Calculated using GIS
DIST_PSTA1	Dummy variable (set 1, if 0.75km < distance to MRT Purple Line ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_PSTA1.25	Dummy variable (set 1, if 1.0km < distance to MRT Purple Line ≤ 1.25km, otherwise 0)	Calculated using GIS
DIST_PSTA1.5	Dummy variable (set 1, if 1.25km < distance to MRT Purple Line ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_PSTA1.75	Dummy variable (set 1, if 1.5km < distance to MRT Purple Line ≤ 1.75km, otherwise 0)	Calculated using GIS
DIST_MR	Distance to main road (km)	Calculated using GIS
DIST_EXP	Distance to expressway ramp (km)	Calculated using GIS
Work and non-work accessibility		
DIST_CBD	Distance to CBD: Siam Square (km)	Calculated using GIS
DIST_SHOPPING	Distance to shopping center (km)	Calculated using GIS
Neighborhood amenity		
MED_INC	Median income (baht)	The Transportation Model of Bangkok Metropolitan Region (e-BUM)
POP_DENS	Population density (persons/sq.km)	
EMP_DENS	Employment density (positions/sq.km)	
SCHOOL_DENS	School density (persons/sq.km)	
Land attribute		
L_AROAD	Access connecting to main roads (1/0)	Satellite image
LAND_PRICE	Land price (baht/sq.m)	Treasury Department

Land attribute refers to main roads connectivity and land price (baht/sq.m). For the main road connectivity, most of the land parcels are located on small roads branching out of main road. Some of these sub-roads connect to the adjacent main road as illustrated in Figure 4 - 4. The value is set to 1 if land parcels being located in small road branching off the main road and that small road can access many directions, and set to 0 otherwise.

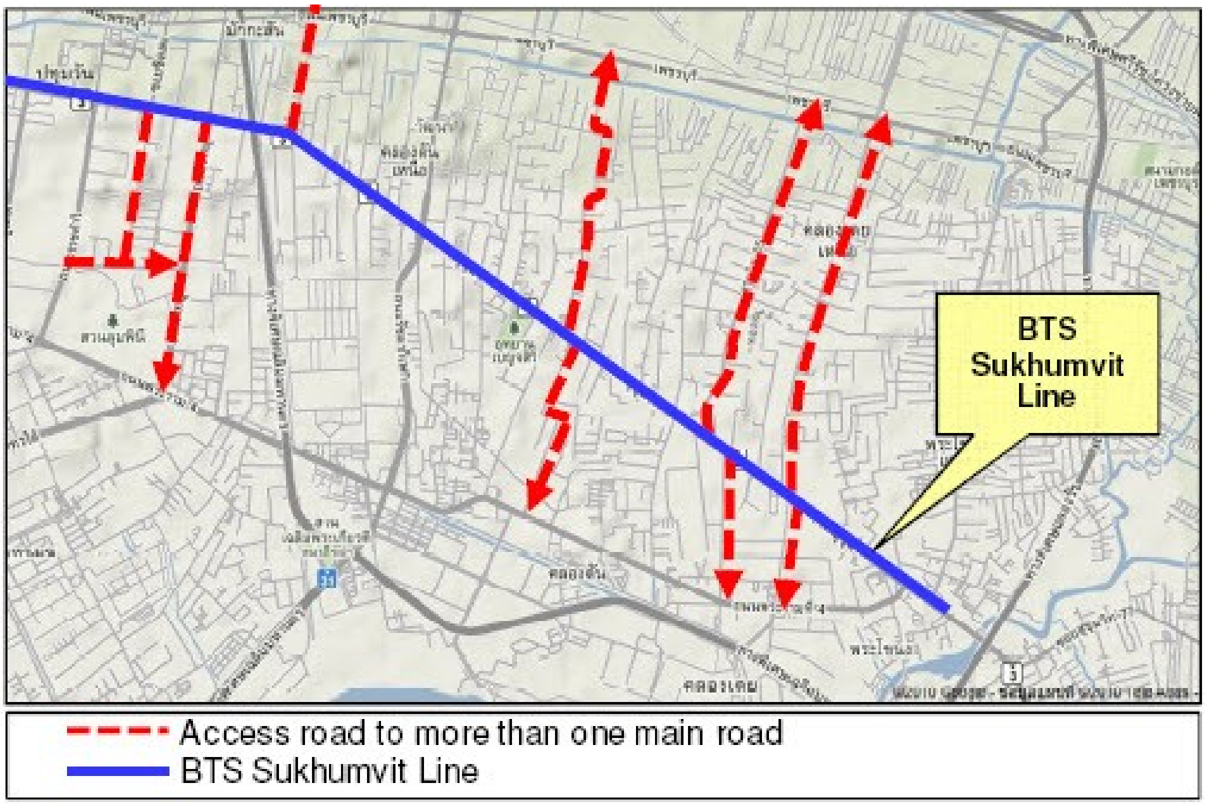

Figure 4 - 4 Access Roads Connecting to Main Roads Sample
Source: Vichiensan *et al.* (2011)

Next, the land price is not distinguished in types of land use. This variable refers to assessed land price (baht/sq.m). The government appraised land value was obtained from the assessed land value reports, which were published by The Treasury Department, Thailand. The period time of land price is during the year 2008 and 2011. Typically, assessed value (price) is the value used by local governments to determine the property taxes. This is generally an unrealistic value. Often times too low, but sometimes high; however, it often bears relationship to the real value of property. Although the assessed land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand. I would expect the estimated coefficient of this variable to be consistently negative, meaning that land development is more likely to be converted in lower land price.

4.5 Descriptive Statistics in Land Use and its Attributes

This section provides descriptive statistics of the land use data set along the urban rail transit corridors: BTS Skytrain, MRT Blue Line, Airport Rail Link and MRT Purple Line at the representative stations. The data includes the distribution of land for the years of 2004 and 2010.

4.5.1 Descriptive Statistics: Land Use Changes along BTS Skytrain and MRT Blue Line

The thirteen BTS Skytrain stations including Chit Lom station, Phloen Chit station, Nana station, Asok station, Phrom Phong station, Thong Lor station, Ekkamai station, Phra Khanong station, On

Nut station, Ratcha Damri station, Sala Daeng station, Chong Nonsi station and Surasak station and the eleven MRT Blue Line stations including Lat Phrao station, Ratchadapisek station, Sutthisan station, Huai Khwang station, Thailand Cultural center station, Rama 9 station, Phetchaburi station, Sukhumvit station, Queen Sirikit Conventional Center Lumphini station, and Silom station were selected to analyze the conversions. The type of land use which was focused as the initial state of land conversions along the BTS Skytrain and MRT Blue Line corridor is undeveloped land parcels.

To identify the remarkable land use change between 2004 and 2010, this study tracked the land use change of 6.56 square kilometer of undeveloped land parcels at the same address along the BTS Skytrain and MRT Blue Line corridor. Around 70 percent of undeveloped land area was unchanged. Among the land use changed parcels, this study chose five types of land use conversion: from undeveloped land to attached housing (0.32 percent), detached housing (3.81 percent), high-rise residential (16.77 percent), to non-residential (10.37 percent). Figure 4 - 5 shows the locations of converted parcels comparing between 2004 and 2010 with reference to the BTS Skytrain and MRT Blue Line corridor.

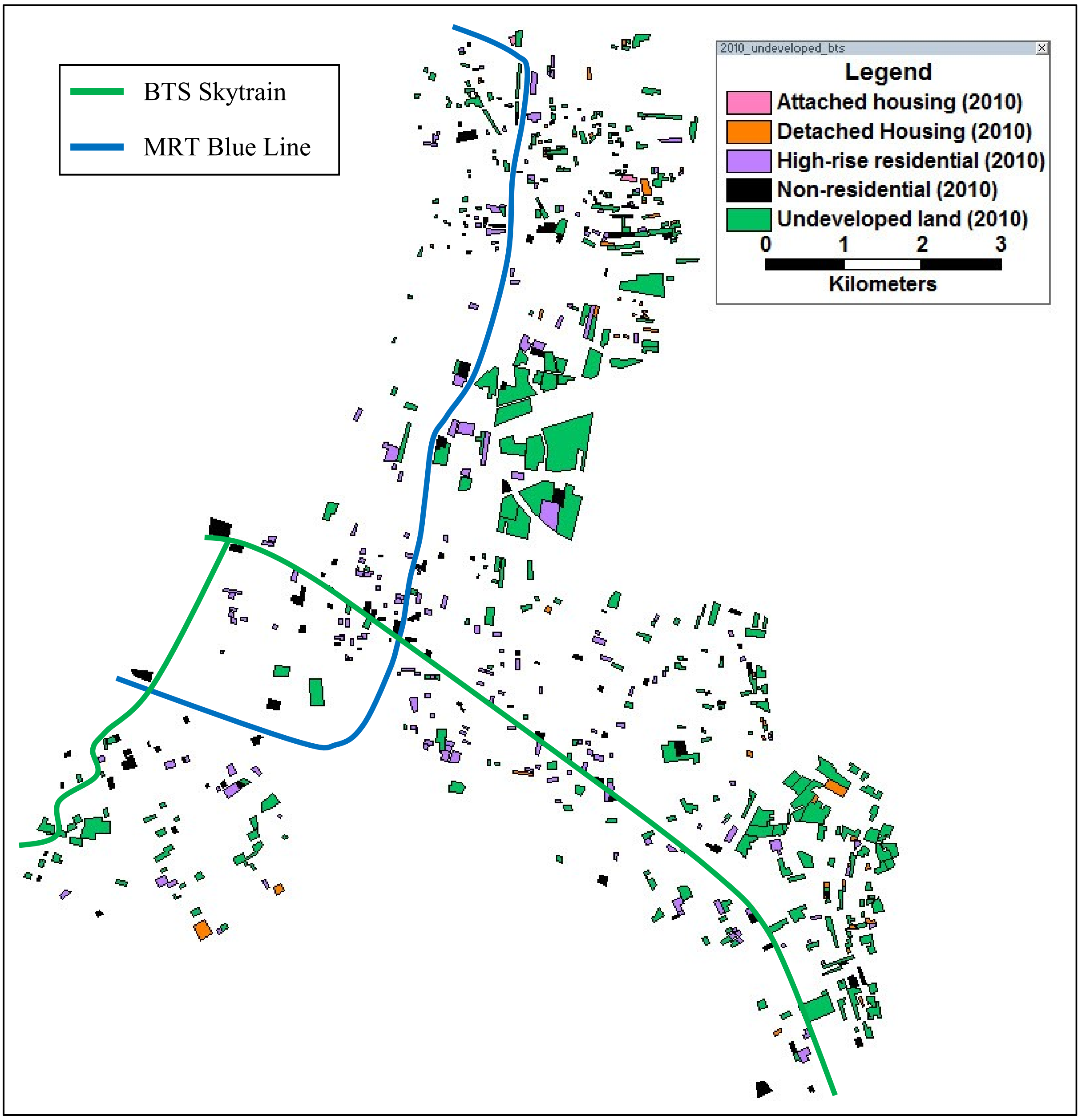

Figure 4 - 5 Locations of Converted Parcels along BTS Skytrain and MRT Blue Line Corridor

According the land use change data presented above, I grouped attached housing, detached housing and other residential property (e.g. twin house, and row house) into low intensity housing category. Thus, land use change models focus on land parcels that convert regarding to four categories: undeveloped land (agricultural land or no buildings), residential (detached house, semi-detached house, twin house, and row house), high-rise residential (condominium and apartment) and non-residential (commercial and industrial).Satellite image in the given areas were divided into rows and columns, which form a regular grid structure of equal size. Each grid cell, 20 x 20 meters, was regarded as a point in the area. Table 4 - 3 shows the number of grid cell converted from undeveloped land to other types between 2004 and 2010.

The total number of grid cells for undeveloped land in the year 2004 was 24,363 grid cells and these cells were changed to the types of land uses in the year 2010: to residential (1,197 grid cells), to high-residential uses (4,548 grid cells) and to non-residential land uses (2,728 grid cells).

Table 4 - 3 Number of Grid Cell Changed from Undeveloped Land between 2004 and 2010 along BTS Skytrain and MRT Blue Line Corridor

		Number of Grid Cells
Changed:	To residential (in 2010)	1,197
	To high-rise residential (in 2010)	4,548
	To non-residential (in 2010)	2,728
Unchanged:	Undeveloped (in 2010)	15,890
Total		24,363

Table 4 - 4 to Table 4 - 6 show the descriptive statistics for each land use change category between 2004 and 2010 along the BTS Skytrain and MRT Blue Line. Among land use change categories, the conversions from undeveloped land to high-rise residential and non-residential uses tended to be closest to the stations and the conversions to residential uses tended to be farthest as expected. Additionally, mostly non-residential uses in this area are office buildings. Specifically, undeveloped land changes to residential uses were more likely to occur from each representative station of the BTS Skytrain and MRT Blue Line more than 5 kilometers. The average shortest distance of the conversions to residential uses was found at Thailand Cultural Center station (5.09 kilometers) and Thong Lor station (5.22 kilometers), respectively. Both stations are located in nearly the end of each line. In the other word, the conversion to residential uses was not occurring in the city core, opposite the conversions to high-rise residential and non-residential uses. Average shortest distance of the conversions to high-residential and non-residential was 3.50 and 3.91 kilometers at Phetchaburi station and Sukhumvit station, respectively. Both stations are able to connect to the other urban rail transit line such as Makkasan station of Airport Rail Link and Asok station of BTS Skytrain. Furthermore, these stations are located in the core area of Bangkok Metropolitan Region. Other key variable for local transportation accessibility, non-residential converted parcels were closer to main road and expressway access than other land use change categories as expected.

In term of work and non-work accessibility variable, the change of undeveloped land to high-residential and non-residential uses was emerged closer to the central business district (CBD) which is the city center of Bangkok Metropolitan Region than residential uses, e.g., on average, the conversion to high-residential and non-residential uses was found within 5.25 and 5.05, respectively, versus within 7.31 kilometers for residential uses. Likewise, the conversion to high-rise residential uses tended to occur near the shopping center approximately within 1.83 kilometers and followed by the conversion to non-residential uses within 1.96 kilometers.

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Table 4 - 4 Descriptive Statistics for Land Converting from Undeveloped Land to Residential Land along BTS Skytrain and MRT Blue Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	1,197	0.05	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest station (km)	1,197	1.49	0.12	2.36
Distance to nearest BTS Skytrain station (km)				
- Distance to Chit Lom station	1,197	6.64	1.39	9.39
- Distance to Phloen Chit station	1,197	6.22	0.83	8.81
- Distance to Nana station	1,197	5.81	0.31	8.01
- Distance to Asok station	1,197	5.58	0.45	8.03
- Distance to Phrom Phong station	1,197	5.31	1.10	8.42
- Distance to Thong Lor station	1,197	5.22	0.47	8.97
- Distance to Ekkamai station	1,197	5.28	1.15	9.54
- Distance to Phra Khanong station	1,197	5.42	1.47	10.14
- Distance to On Nut station	1,197	5.95	1.04	11.37
- Distance to Ratcha Damri station	1,197	6.92	1.57	9.43
- Distance to Sala Daeng station	1,197	7.47	2.35	10.17
- Distance to Chong Nonsi station	1,197	7.93	2.36	10.88
- Distance to Surasak station	1,197	8.72	2.42	11.79
Distance to nearest MRT Blue Line station (km)				
- Distance to Lat Phrao station	1,197	7.04	0.12	13.01
- Distance to Ratchadapisek station	1,197	6.43	0.51	12.29
- Distance to Sutthisan station	1,197	5.69	0.50	11.18
- Distance to Huai Khwang station	1,197	5.26	0.70	10.21
- Distance to Thailand Cultural Center station	1,197	5.09	0.96	9.20
- Distance to Rama 9 station	1,197	5.27	2.17	8.68
- Distance to Phetchaburi station	1,197	5.35	1.47	8.10
- Distance to Sukhumvit station	1,197	5.55	0.48	7.97
- Distance to Queen Sirikit Conventional station	1,197	5.92	1.58	9.41
- Distance to Lumpini station	1,197	6.74	1.58	9.79
- Distance to Silom station	1,197	7.22	2.01	9.89
Distance to main road (km)	1,197	0.87	0.07	1.79
Distance to expressway ramp (km)	1,197	1.49	0.21	2.36
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	1,197	7.31	2.32	10.29
Distance to shopping center (km)	1,197	2.95	0.38	4.48
Neighborhood amenity				
Median income (baht/month)	1,197	28,278	18,978	42,646
Population density (persons/sq.km)	1,197	11,672	5,168	42,435
Household density (households/sq.km)	1,197	3,311	1,585	11,943
Employment density (positions/sq.km)	1,197	7,148	1,574	43,622
School density (student/sq.km)	1,197	2,061	0	6,053
Land attribute				
Road connection (1/0)	1,197	0.65	0	1
Land price (baht/sq.m)	1,197	145,414	51,000	320,000

Table 4 - 5 Descriptive Statistics for Land Converting from Undeveloped Land to High-Rise Residential Land along BTS Skytrain and MRT Blue Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	4,548	0.19	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest station (km)	4,548	0.78	0.06	2.52
Distance to nearest BTS Skytrain station (km)				
- Distance to Chit Lom station	4,548	4.54	0.27	9.23
- Distance to Phloen Chit station	4,548	4.13	0.14	8.68
- Distance to Nana station	4,548	3.78	0.22	7.91
- Distance to Asok station	4,548	3.64	0.16	7.53
- Distance to Phrom Phong station	4,548	3.65	0.17	8.13
- Distance to Thong Lor station	4,548	3.96	0.22	8.91
- Distance to Ekkamai station	4,548	4.35	0.06	9.52
- Distance to Phra Khanong station	4,548	4.83	0.20	10.16
- Distance to On Nut station	4,548	5.86	0.84	11.43
- Distance to Ratcha Damri station	4,548	4.82	0.17	9.20
- Distance to Sala Daeng station	4,548	5.46	0.58	9.55
- Distance to Chong Nonsi station	4,548	5.99	0.39	10.27
- Distance to Surasak station	4,548	6.86	0.54	11.22
Distance to nearest MRT Blue Line station (km)				
- Distance to Lat Phrao station	4,548	7.01	0.60	13.37
- Distance to Ratchadapisek station	4,548	6.35	0.18	12.66
- Distance to Sutthisan station	4,548	5.37	0.12	11.55
- Distance to Huai Khwang station	4,548	4.62	0.06	10.54
- Distance to Thailand Cultural Center station	4,548	3.94	0.40	9.46
- Distance to Rama 9 station	4,548	3.62	0.36	8.82
- Distance to Phetchaburi station	4,548	3.50	0.31	8.15
- Distance to Sukhumvit station	4,548	3.62	0.20	7.47
- Distance to Queen Sirikit Conventional station	4,548	4.16	0.42	8.94
- Distance to Lumpini station	4,548	4.78	0.48	9.19
- Distance to Silom station	4,548	5.20	0.70	9.25
Distance to main road (km)	4,548	0.36	0.03	1.79
Distance to expressway ramp (km)	4,548	1.47	0.23	3.72
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	4,548	5.25	0.83	10.08
Distance to shopping center (km)	4,548	1.83	0.15	4.76
Neighborhood amenity				
Median income (baht/month)	4,548	30,554	18,978	65,095
Population density (persons/sq.km)	4,548	13,681	39,87	41,710
Household density (households/sq.km)	4,548	3,877	1,252	10,874
Employment density (positions/sq.km)	4,548	17,358	1,063	115,333
School density (student/sq.km)	4,548	4,713	0	22,135
Land attribute				
Road connection (1/0)	4,548	0.53	0	1
Land price (baht/sq.m)	4,548	238,450	51,000	500,000

Table 4 - 6 Descriptive Statistics for Land Converting from Undeveloped Land to Non-Residential Land along BTS Skytrain and MRT Blue Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	2,728	0.11	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest station (km)	2,728	0.83	0.05	2.76
Distance to nearest BTS Skytrain station (km)				
- Distance to Chit Lom station	2,728	4.47	0.38	9.67
- Distance to Phloen Chit station	2,728	4.18	0.17	9.09
- Distance to Nana station	2,728	3.96	0.10	8.31
- Distance to Asok station	2,728	3.92	0.10	7.63
- Distance to Phrom Phong station	2,728	4.06	0.25	8.20
- Distance to Thong Lor station	2,728	4.39	0.30	8.90
- Distance to Ekkamai station	2,728	4.73	0.05	9.57
- Distance to Phra Khanong station	2,728	5.16	0.57	10.21
- Distance to On Nut station	2,728	6.05	0.10	11.47
- Distance to Ratcha Damri station	2,728	4.65	0.90	9.67
- Distance to Sala Daeng station	2,728	5.12	0.18	9.58
- Distance to Chong Nonsi station	2,728	5.57	0.07	9.88
- Distance to Surasak station	2,728	6.40	0.14	10.82
Distance to nearest MRT Blue Line station (km)				
- Distance to Lat Phrao station	2,728	7.71	0.57	13.80
- Distance to Ratchadapisek station	2,728	7.06	0.42	13.09
- Distance to Sutthisan station	2,728	6.06	0.45	11.98
- Distance to Huai Khwang station	2,728	5.30	0.42	10.97
- Distance to Thailand Cultural Center station	2,728	4.59	0.25	9.88
- Distance to Rama 9 station	2,728	4.18	0.14	9.24
- Distance to Phetchaburi station	2,728	3.95	0.40	8.55
- Distance to Sukhumvit station	2,728	3.91	0.06	7.63
- Distance to Queen Sirikit Conventional station	2,728	4.35	1.03	8.98
- Distance to Lumpini station	2,728	4.62	0.12	9.03
- Distance to Silom station	2,728	4.91	0.24	9.35
Distance to main road (km)	2,728	0.31	0.02	1.47
Distance to expressway ramp (km)	2,728	1.41	0.05	3.59
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	2,728	5.05	0.74	10.54
Distance to shopping center (km)	2,728	1.96	0.10	4.88
Neighborhood amenity				
Median income (baht/month)	2,728	31,324	17,643	65,095
Population density (persons/sq.km)	2,728	12,761	3,987	35,262
Household density (households/sq.km)	2,728	3,817	1,252	9,064
Employment density (positions/sq.km)	2,728	25,459	1,063	115,333
School density (student/sq.km)	2,728	5,827	0	29,236
Land attribute				
Road connection (1/0)	2,728	0.34	0	1
Land price (baht/sq.m)	2,728	252,110	51,000	500,000

Among neighborhood amenity variables, the conversion to high-rise residential and non-residential uses generally tended to be in the densest setting such as high population, household, employment and school density and within the higher median income area while the conversion to residential uses tended to be the sparsest.

Most conversion to residential uses were located on small roads branching than other land uses. Some of these sub-roads connect to the adjacent main road which provides easy access to many adjacent main roads. Finally, the descriptive statistics indicated that the conversion to high-residential and non-residential uses was found in the higher land value area than the conversion to residential uses, e.g., on average, 145,000 baht/sq.m ($4,858 per sq.m[1]) for residential uses, versus 238,000 baht/sq.m ($7,973 per sq.m) and 252,000 baht/sq.m ($8,442 per sq.m) for high-rise residential and non-residential uses, respectively

4.5.2 Descriptive Statistics: Land Use Changes along Airport Rail Link

The five Airport Rail Link stations which will be analyzed include Ramkhamhaeng station, Hua Mak station, Baan Tab Chang station, Lat Krabang station and Suvarnabhumi Airport station. Land use changes at Airport Rail Link stations were examined between 2004 and 2010 which was before construction the Airport Rail Link and after the first years of operation. The type of land use which was focused the land conversions along Airport Rail Link corridor is undeveloped land parcels.

To identify the remarkable land use change between 2004 and 2010, this study tracked the land use change of 28.73 square kilometer of undeveloped land parcel at the same address along the Airport Rail Link corridor. 76.16 percent of undeveloped land area was unchanged. Among the land use changed parcels, this study chose five types of land use conversion by the percentage rank of converted parcels and the remarkable change in terms of use: from undeveloped land to attached housing (2.75 percent), to detached housing (7.59 percent), high-rise residential (0.63 percent), to non-residential (4.59 percent). Figure 4 - 6 shows the locations of converted parcels comparing between 2004 and 2010 with reference to the Airport Rail Link corridor.

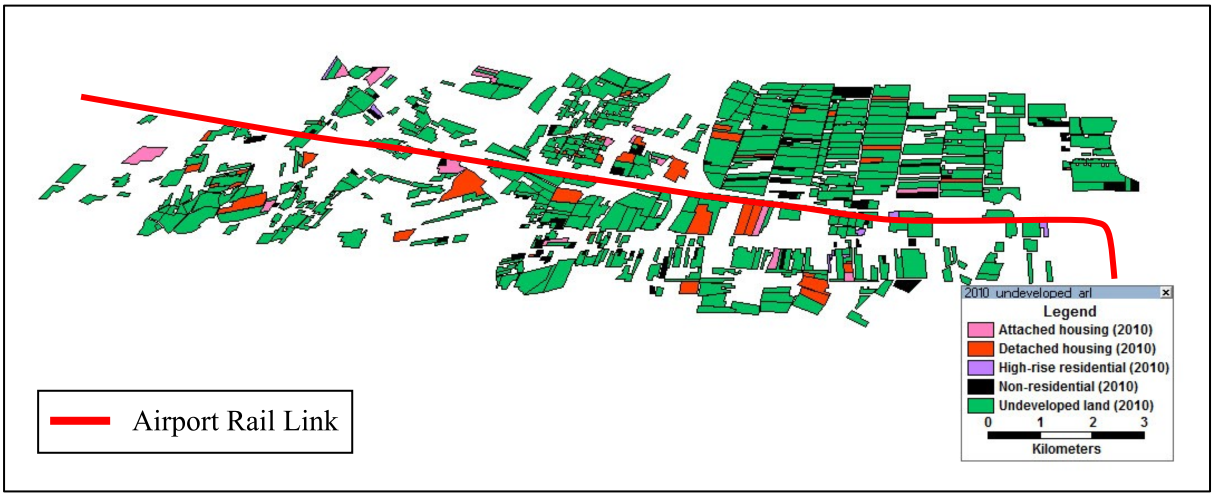

Figure 4 - 6 Locations of Converted Parcels along Airport Rail Link Corridor

According the land use change data presented above, I grouped attached housing, detached housing and other residential property (e.g. twin house, and row house) into low density housing category. Thus, land use change models focus on land parcels that convert regarding to four categories:

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[1] Exchange rate is 1 THB = 0.0335 USD (26 February 2013)

undeveloped land (agricultural land or no buildings), residential (detached house, semi-detached house, twin house, and row house), high-rise residential (condominium and apartment) and non-residential (commercial and industrial). Table 4 - 7 shows the number of grid cell converted from undeveloped land to other types between 2004 and 2010.

The total number of grid cells for undeveloped land in the year 2004 was 85,812 grid cells and these cells were changed to the types of land uses in the year 2010: to residential (9,147 grid cells), to high-residential uses (only 678 grid cells) and to non-residential land uses (4,601 grid cells).

According to the number of grid cells for undeveloped land along the Airport Rail Link corridor were much more than the number of grid cells along the BTS Skytrain and MRT Blue Line due to the location of Airport Rail Link network. Most stations of Airport Rail Link are located in the outer city where they are a lot of undeveloped land parcels compared to adjacent area of the BTS Skytrain and MRT Blue Line.

Table 4 - 7 Number of Grid Cell Changed from Undeveloped Land between 2004 and 2010 along Airport Rail Link Corridor

		Number of grid cells
Changed:	To residential (in 2010)	9,147
	To high-rise residential (in 2010)	678
	To non-residential (in 2010)	4,601
Unchanged:	Undeveloped (in 2010)	71,386
Total		85,812

Table 4 - 8 to Table 4 - 10 show the descriptive statistics for each land use change category between 2004 and 2010 along the Airport Rail Link. Among land use change categories, the conversions from undeveloped land to residential and high-rise residential uses tended to be closest to the stations and the conversions to non-residential uses tended to be farthest as expected. Additionally, mostly non-residential uses in this area are warehouses and factories. The average shortest distance of the conversions to residential uses was found at Baan Tab Chang station (3.78 kilometers) and Hua Mak station (5.42 kilometers), respectively. On the other hand, the average shortest distance of the conversions to high-residential and non-residential was 5.29 and 4.34 kilometers at Lat Krabang station and Baan Tab Chang station, respectively. Other key variable for local transportation accessibility, residential and high-rise residential converted parcels were closer to main road than the conversion to non-residential uses. This statistics is quite different from the conversions along the BTS Skytrain and MRT Blue Line. For the distance to expressway access, the conversion to residential, high-residential and non-residential uses was found within 7.11 kilometers, 8.16 kilometers, and 9.43 kilometers, respectively.

In term of work and non-work accessibility variable, the change of undeveloped land to residential, high-residential and non-residential uses was emerged farther to the central business district (CBD) which is the city center of Bangkok Metropolitan Region, e.g., on average, the conversion to residential, high-residential and non-residential uses was found within 16.37 kilometers, 18.78 kilometers, and 19.51 kilometers respectively. As explained, the location network of Airport Rail Link is served the outer area. For the distance to shopping center, the conversion to residential uses tended to occur near the shopping center approximately within 5.98 kilometers which opposite the results of land use change along the BTS Skytrain and MRT Blue Line and followed by the conversion to high-residential uses within 7.57 kilometers.

Among neighborhood amenity variable, the conversion to high-rise residential and non-residential uses generally tended to be in the sparsest setting such as population, household, employment and school density compared with the land use change along the BTS Skytrain and MRT Blue Line.

Most conversion to residential and non-residential uses were located on small roads branching than other land uses. Some of these sub-roads connect to the adjacent main road which provides easy access to many adjacent main roads. Finally, the descriptive statistics indicated that the conversion to residential and high-residential uses was found in the higher land value area than the conversion to non-residential uses, e.g., on average, 32,000 baht/sq.m ($1,072 per sq.m) for non-residential uses, versus 46,000 baht/sq.m ($1,541 per sq.m) and 44,000 baht/sq.m ($1,474 per sq.m) for residential and high-rise residential uses, respectively. In addition, the land value for the conversion to non-residential uses is lower than other types because non-residential uses in this area are warehouses and factories. Therefore, the conversion occurred in the lower land value area.

Table 4 - 8 Descriptive Statistics for Land Converting from Undeveloped Land to Residential Land along Airport Rail Link Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	9,147	0.11	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest Airport Rail Link station (km)	9,147	1.86	0.58	18.21
- Distance to Ramkhamhaeng station	9,147	9.21	0.81	13.40
- Distance to Hua Mak station	9,147	5.42	0.98	0.91
- Distance to Baan Tab Chang station	9,147	3.78	0.58	15.40
- Distance to Lat Krabang station	9,147	7.10	0.74	16.38
- Distance to Suvarnabhumi station	9,147	8.64	3.34	3.58
Distance to main road (km)	9,147	0.55	0.02	2.15
Distance to expressway ramp (km)	9,147	7.11	0.31	12.94
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	9,147	16.37	7.90	25.41
Distance to shopping center (km)	9,147	5.98	1.45	13.86
Neighborhood amenity				
Median income (baht/month)	9,147	30,103	16,493	45,347
Population density (persons/sq.km)	9,147	6,964	346	43,390
Household density (households/sq.km)	9,147	2,298	134	16,351
Employment density (positions/sq.km)	9,147	2,981	318	13,601
School density (student/sq.km)	9,147	1,318	0	6,062
Land attribute				
Road connection (1/0)	9,147	0.44	0	1
Land price (baht/sq.m)	9,147	46,797	21,000	100,000

Table 4 - 9 Descriptive Statistics for Land Converting from Undeveloped Land to High-Rise Residential Land along Airport Rail Link Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	678	0.01	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest Airport Rail Link station (km)	678	1.66	0.89	3.17
- Distance to Ramkhamhaeng station	678	11.62	4.29	17.83
- Distance to Hua Mak station	678	7.32	0.97	13.00
- Distance to Baan Tab Chang station	678	5.45	1.57	7.99
- Distance to Lat Krabang station	678	5.29	0.89	12.16
- Distance to Suvarnabhumi station	678	7.18	3.62	13.72
Distance to main road (km)	678	0.38	0.02	1.93
Distance to expressway ramp (km)	678	8.16	3.12	12.27
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	678	18.78	11.41	25.03
Distance to shopping center (km)	678	7.57	1.44	13.09
Neighborhood amenity				
Median income (baht/month)	678	32,692	19,821	45,347
Population density (persons/sq.km)	678	6,061	2,881	10,731
Household density (households/sq.km)	678	1,993	831	4,532
Employment density (positions/sq.km)	678	3,361	320	9,764
School density (student/sq.km)	678	1,960	282	6,062
Land attribute				
Road connection (1/0)	678	0.30	0	1
Land price (baht/sq.m)	678	44,491	21,000	100,000

Table 4 - 10 Descriptive Statistics for Land Converting from Undeveloped Land to Non-Residential Land along Airport Rail Link Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	4,601	0.05	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest Airport Rail Link station (km)	4,601	2.08	0.28	3.60
- Distance to Ramkhamhaeng station	4,601	12.33	2.77	19.47
- Distance to Hua Mak station	4,601	7.76	0.28	14.66
- Distance to Baan Tab Chang station	4,601	4.34	0.35	9.67
- Distance to Lat Krabang station	4,601	4.67	0.80	13.35
- Distance to Suvarnabhumi station	4,601	6.67	2.57	14.49
Distance to main road (km)	4,601	0.54	0.03	2.17
Distance to expressway ramp (km)	4,601	9.43	1.60	13.52
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	4,601	19.51	9.94	26.68
Distance to shopping center (km)	4,601	8.32	1.48	14.95
Neighborhood amenity				
Median income (baht/month)	4,601	32,380	19,821	45,347
Population density (persons/sq.km)	4,601	4,224	1,329	31,308
Household density (households/sq.km)	4,601	1,246	368	11,798
Employment density (positions/sq.km)	4,601	1,786	318	9,814
School density (student/sq.km)	4,601	978	185	6,062
Land attribute				
Road connection (1/0)	4,601	0.60	0	1
Land price (baht/sq.m)	4,601	32,407	15,000	100,000

4.5.3 Descriptive Statistics: Land Use Changes along MRT Purple Line

The nine MRT Purple Line stations which will be analyzed include Khlong Bang Phai station, Bang Yai Market station, Bang Yai Intersection station, Bang Phlu station, Bang Rak Yai station, Tha It station, Sai Ma station, Phra Nung Khlao Bridge station and Nonthaburi Intersection station. Land use changes at MRT Purple Line stations are examined between 2004 and 2010 which was before and during construction the MRT Purple Line. The type of land use which was focused the land conversions along the MRT Purple Line corridor is undeveloped land parcels.

To identify the remarkable land use change between 2004 and 2010, this study tracked the land use changes of 25.80 square kilometer of undeveloped land parcel with the same address along the MRT Purple Line corridor. 76.16 percent of undeveloped land area was unchanged. Among the land use changed parcels, this study chose five types of land use conversion by the percentage rank of converted parcels and the remarkable change in terms of use: from undeveloped land to attached housing (3.10 percent), to detached housing (16.28 percent), high-rise residential (1.05 percent), to non-residential (3.33 percent). Figure 4 - 7 shows the locations of converted parcels comparing between 2004 and 2010 with reference to the MRT Purple Line corridor.

Figure 4 - 7 Locations of Converted Parcels along MRT Purple Line Corridor

According the land use change data presented above, I grouped attached housing, detached housing and other residential property (e.g. twin house, and row house) into low density housing category. Thus, land use change models focus on land parcels that convert regarding to five categories: undeveloped land (agricultural land or no buildings), low density housing (detached house, semi-detached house, twin house, and row house), high density housing (condominium and apartment) and non-residential property (commercial and industrial).Satellite image in the given areas were divided into rows and columns, which form a regular grid structure of equal size. Each grid cell, 20 x 20 meters, was regarded as a point in the area. Table 4 - 11 shows the number of grid cell converted from undeveloped land to other types between 2004 and 2010.

The total number of grid cells for undeveloped land in the year 2004 was 84,201 grid cells and these cells were changed to the types of land uses in the year 2010: to residential (16,640 grid cells), to high-residential uses (1,045 grid cells) and to non-residential land uses (3,668 grid cells).

According to the number of grid cells for undeveloped land along the MRT Purple Line corridor were much more than the number of grid cells along the BTS Skytrain and MRT Blue Line but nearly the same as the number of grid cells along the Airport Rail Link corridor due to the location of MRT Purple Line network. Most stations of Airport Rail Link are located in the outer city where they are a lot of undeveloped land parcels compared to adjacent area of the BTS Skytrain and MRT Blue Line.

Table 4 - 11 Number of Grid Cell Changed from Undeveloped Land between 2004 and 2010 along MRT Purple Line Corridor

		Number of grid cells
Changed:	To residential	16,640
	To high-rise residential	1,045
	To non-residential	3,668
Unchanged:	Undeveloped	62,848
Total		84,201

Table 4 - 12 to Table 4 - 14 show the descriptive statistics for each land use change category between 2004 and 2010 along the MRT Purple Line. Among land use change categories, the conversions from undeveloped land to high-rise residential and non-residential uses tended to be closest to the stations and the conversions to residential uses tended to be farthest as expected. The average shortest distance of the conversions to residential uses was found at Bamg Phlu station (3.52 kilometers) and Bang Rak Yai station (3.58 kilometers) and followed by Bang Yai Intersection station (3.98 kilometers), respectively. On the other hand, the average shortest distance of the conversions to high-residential and non-residential was 3.97 and 3.68 kilometers at Bang Rak Yai station, respectively. Other key variable for local transportation accessibility, high-rise residential and non-residential converted parcels were closer to main road than the conversion to residential uses. For the distance to expressway access, the conversion to residential, high-residential and non-residential uses was found within 10.41 kilometers, 9.73 kilometers, and 9.45 kilometers, respectively.

For work and non-work accessibility variable, the change of undeveloped land to residential, high-residential and non-residential uses was emerged farther to the central business district (CBD) which is the city center of Bangkok Metropolitan Region, e.g., on average, the conversion to residential, high-residential and non-residential uses was found within 17.77 kilometers, 17.45 kilometers, and 17.26 kilometers, respectively. As explained, the location network of MRT Purple Line is served the outer area. For the distance to shopping center, the conversion to residential uses tended to occur far from the shopping center approximately 6.68 kilometers and followed by the conversion to high-residential uses within 6.14 kilometers.

Among neighborhood amenity variable, the conversion to high-rise residential and non-residential uses generally tended to be in the sparsest setting such as population, household, employment and school density compared with the land use change along the BTS Skytrain and MRT Blue Line.

Most conversion to residential and non-residential uses were located on small roads branching than other land uses. Some of these sub-roads connect to the adjacent main road which provides easy access to many adjacent main roads. Finally, the descriptive statistics indicated that the conversion to residential and high-residential uses was found in the higher land value area than the conversion to non-residential uses, e.g., on average, 27,000 baht/sq.m ($1,072 per sq.m) for residential uses, versus 32,000 baht/sq.m ($1,072 per sq.m) and 30,000 baht/sq.m ($905 per sq.m) for high-rise residential and non-residential uses, respectively.

Table 4 - 12 Descriptive Statistics for Land Converting from Undeveloped to Residential Land along MRT Purple Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	16,640	0.20	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest MRT Purple Line station (km)	16,640	1.44	0.17	3.06
- Distance to Khlong Bang Phai station	16,640	4.63	0.34	12.00
- Distance to Bang Yai Market station	16,640	4.27	0.83	11.58
- Distance to Bang Yai Intersection station	16,640	3.98	0.53	10.94
- Distance to Bang Phlu tion station	16,640	3.52	0.64	8.98
- Distance to Bang Rak Yai station	16,640	3.58	0.29	7.89
- Distance to Tha It station	16,640	3.96	0.52	7.45
- Distance to Sai Ma station	16,640	4.61	0.17	8.83
- Distance to Phra Numg Khlao Bridge station	16,640	5.18	0.56	9.69
- Distance to Nonthaburi Intersection station	16,640	6.43	0.29	11.34
- Distance to Sripornsawan station	16,640	7.38	0.42	12.41
- Distance to Nonthaburi Government station	16,640	8.51	0.34	13.61
- Distance to Ministry of Public Health station	16,640	8.89	0.27	14.00
Distance to main road (km)	16,640	0.82	0.03	1.94
Distance to expressway ramp (km)	16,640	10.41	2.34	15.53
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	16,640	17.77	11.60	22.21
Distance to shopping center (km)	16,640	6.68	0.14	11.63
Neighborhood amenity				
Median income (baht/month)	16,640	29,837	25,339	41,595
Population density (persons/sq.km)	16,640	9,459	467	39,825
Household density (households/sq.km)	16,640	2,803	131	11,591
Employment density (positions/sq.km)	16,640	1,627	74	11,806
School density (student/sq.km)	16,640	761	0	7,173
Land attribute				
Road connection (1/0)	16,640	0	1	0.13
Land price (baht/sq.m)	16,640	26,962	12,000	55,000

Table 4 - 13 Descriptive Statistics for Land Converting from Undeveloped to High-Rise Residential Land along MRT Purple Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	1,045	0.01	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest MRT Purple Line station (km)	1,045	0.91	0.14	1.82
- Distance to Khlong Bang Phai station	1,045	4.98	0.51	11.92
- Distance to Bang Yai Market station	1,045	4.62	0.78	11.52
- Distance to Bang Yai Intersection station	1,045	4.46	0.20	10.89
- Distance to Bang Phlu tion station	1,045	4.10	1.42	8.90
- Distance to Bang Rak Yai station	1,045	3.97	0.95	7.80
- Distance to Tha It station	1,045	4.10	0.49	6.88
- Distance to Sai Ma station	1,045	4.65	0.93	8.22
- Distance to Phra Numg Khlao Bridge station	1,045	5.05	0.14	9.12
- Distance to Nonthaburi Intersection station	1,045	5.95	0.36	10.71
- Distance to Sripornsawan station	1,045	6.75	0.43	11.75
- Distance to Nonthaburi Government station	1,045	7.82	0.71	12.94
- Distance to Ministry of Public Health station	1,045	8.23	0.38	13.14
Distance to main road (km)	1,045	0.56	0.02	1.53
Distance to expressway ramp (km)	1,045	9.73	2.32	14.92
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	1,045	17.45	11.85	20.81
Distance to shopping center (km)	1,045	6.14	0.26	11.02
Neighborhood amenity				
Median income (baht/month)	1,045	29,043	25,339	41,595
Population density (persons/sq.km)	1,045	9,852	467	32,495
Household density (households/sq.km)	1,045	3,023	131	9,909
Employment density (positions/sq.km)	1,045	2,526	117	11,806
School density (student/sq.km)	1,045	832	0	4,465
Land attribute				
Road connection (1/0)	1,045	0.27	0	1
Land price (baht/sq.m)	1,045	31,947	15,000	55,000

Table 4 - 14 Descriptive Statistics for Land Converting from Undeveloped to Non-Residential Land along MRT Purple Line Corridor

Variables	N	Mean	Min	Max
Dependent Variable				
Land use change	3,668	0.04	0	1
Independent Variables				
Local transportation accessibility				
Distance to nearest MRT Purple Line station (km)	3,668	1.04	0.06	2.46
- Distance to Khlong Bang Phai station	3,668	5.08	0.21	12.09
- Distance to Bang Yai Market station	3,668	4.69	0.36	11.69
- Distance to Bang Yai Intersection station	3,668	4.38	0.34	11.06
- Distance to Bang Phlu tion station	3,668	3.75	0.06	9.08
- Distance to Bang Rak Yai station	3,668	3.68	0.19	7.97
- Distance to Tha It station	3,668	3.89	0.17	7.40
- Distance to Sai Ma station	3,668	4.41	0.63	8.69
- Distance to Phra Numg Khlao Bridge station	3,668	4.81	0.16	9.60
- Distance to Nonthaburi Intersection station	3,668	5.71	0.15	11.15
- Distance to Sripornsawan station	3,668	6.54	0.07	12.16
- Distance to Nonthaburi Government station	3,668	7.61	0.64	13.35
- Distance to Ministry of Public Health station	3,668	8.03	0.23	13.47
Distance to main road (km)	3,668	0.33	0.01	2.04
Distance to expressway ramp (km)	3,668	9.49	2.18	15.34
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	3,668	17.26	11.74	21.24
Distance to shopping center (km)	3,668	5.91	0.15	11.46
Neighborhood amenity				
Median income (baht/month)	3,668	29,599	25,339	41,595
Population density (persons/sq.km)	3,668	13,159	467	39,825
Household density (households/sq.km)	3,668	3,948	131	11,591
Employment density (positions/sq.km)	3,668	2,663	74	11,806
School density (student/sq.km)	3,668	1,117	0	4,465
Land attribute				
Road connection (1/0)	3,668	0.15	0	1
Land price (baht/sq.m)	3,668	30,654	12,000	55,000

4.6 Land Use Model Specification

The models of land use changes are generated based on the discrete choice framework, i.e., multinomial logit model. Most previous and present studies, especially in developing countries case studies are less investigated the spatial effects in the models of land cover changes. Furthermore, few studies is adapt at analyzing satellite image data that is highly disaggregate units and large sample size (Wang and Kockelman, 2006). Thus, the challenge of this section is to adapt analyzing satellite image data to appreciate the facets of this land cover changes impacts.

An application of discrete choice model, i.e., multinomial logit model (ML) analyzed based on the random utility maximization framework (RUM) was first introduced by McFadden (1974). It is designed to estimate the parameters of a multivariate explanatory model in situations where the dependent variable is dichotomous or categories. This method yields coefficients for each variable based on a sample of data that is grid cells. The model specification (Schneider and Pontinus, 2001; Serneels and Lambin, 2001) will be described in next section.

The dependent variable is a four dimensional vector of land use categories, presenting undeveloped land, residential uses, high-rise residential uses and non-residential uses. The ML model indentifies the role and intensity of explanatory variables X_n in the prediction of the probability of one state of the dependent variable, which is defined as a categorical variable Y.

$$P_{nj} = \frac{\exp(V_{nj})}{\sum_{j=1}^{J} \exp(V_{nJ})} \qquad j = 1, \ldots, 4 \tag{4.1}$$

$$U_{nj} = \beta X_{nj} + \varepsilon_{nj} = V_{nj} + \varepsilon_{nj} \tag{4.2}$$

where P_{nj} is the probability of j land use category for grid cell n. U_{nj} is the utility of j land use category for grid cell n while β_{nk} is parameter which reflects the relation between the explanatory variables and the land use category j. and ε_{nj} is a random unobserved component of utility, assumed to be independent and identically distributed (iid)[2]. X_{nj} is a vector of explanatory variables for grid cell n. The term $\boldsymbol{\beta} X_{nj}$ in equation (4.2) is known as the deterministic or systematic component of the utility function, denoted as V.

4.7 Influencing Factors in Determining Land Use Change

This section summarizes and interprets model results for land use conversions between 2004 and 2010 along the BTS Skytrain, MRT Blue Line, Airport Rail Link and MRT Purple Line.

4.7.1 Land Use Change Model: BTS Skytrain and MRT Blue Line

Table 4 - 15 presents the land use change model for the adjacent area of the BTS Skytrain and MRT Blue Line corridor which was calibrated by the multinomial logit model (ML). To capture the influencing factors in determining land use change model, the model results were estimated based on four categories including local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute. The goodness-of-fit is evaluated by Rho-square.

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[2] An iid assumption on the Gumbel error term imposes the independence of irrelevant alternatives (IIA) property (Train, 2002)

After extensive experimentations with different specifications, the model results were chosen based on the theoretical and statistical significance of the estimated parameters. The results of the final specification are discussed as below.

4.7.1.1 Effects of Local Transportation Accessibility

Local transportation accessibility variable refers to proximity to the rail transit station, main road and the expressway ramp as explained. First, the proximity to the nearest BTS Skytrain and MRT Blue Line station (DIST_BBSTA) has negative effect to the conversion of undeveloped to high-rise residential and non-residential uses but positive effect to the conversion to residential uses, meaning that land whose use changed from undeveloped to residential uses is less likely to be near the BTS Skytrain and MRT Blue Line station while the conversion to high-rise residential and non-residential uses has emerged in areas closer to the station. Not surprising, the probability of converting from undeveloped to residential, high-rise residential and non-residential uses was more likely to appear closer to main road. Next, distance to expressway access (DIST_EXP) has positive sign for the three conversions, indicating that the distance to expressway did not increase the likelihood of conversions to each of the three land use conversion.

4.7.1.2 Effects of Work and Non-Work Accessibility

Work and non-work accessibility variable refers to proximity to the central business district where there are physically concentrated in the inner core of the Bangkok Metropolitan Region: Sukhumvit and Silom Area and another variable is the distance to the nearest shopping center or shopping mall. Not surprisingly, the coefficient of the distance to CBD, it is negative sign for all conversions, indicating that the changes of undeveloped land to residential, high-rise residential and non-residential uses were found that closer to the central business district (CBD). Likewise, the likelihood of converting to high-rise residential and non-residential uses occurred near the shopping center (DIST_SHP). Nevertheless, the distance to shopping center has positive coefficient for the conversion to residential uses, meaning that the conversion was less likely to be near the shopping center.

4.7.1.3 Effects of Neighborhood Amenity

This variable includes the density of each zone (e.g. population per square kilometer, employment per square kilometer as well as student per square kilometer). First, the coefficient of median income variable has negative sign, suggesting that the lower income level, the more conversion they are. As population density surrounding an area grows, the probability of converting from undeveloped land to residential and high-rise residential uses tended to increase. Employment density (EMP_DENS) was associated with a higher likelihood of land use conversion from undeveloped land to non-residential uses. Furthermore, the school density has positive coefficient, indicating that the greater number of school density increased the probability of converting from undeveloped land to high-rise residential and non-residential uses.

4.7.1.4 Effects of Land Attribute

This variable includes the main road connection (L_AROAD) and land value (LAND_PRICE). Firstly, undeveloped land located in small road branching which connect to adjacent main roads was more likely to change to residential and high-rise residential uses. Higher land value is associated with the likelihood of conversions from undeveloped land to high-rise residential and non-residential uses, while lower land value is greatly linked with the conversion of undeveloped land to residential uses. This output confirms that more value land tends to be converted to intensified land uses, such as luxury high-rise residential and high-end non-residential uses.

Table 4 - 15 Land Use Change Model: BTS Skytrain and MRT Blue Line

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_BBSTA	5.3264	6.9156	***	-4.3402	-9.8035	***	-1.3760	-2.7222	***
DIST_MR	-5.6514	-7.3298	***	-14.3565	-21.8169	***	-16.3486	-19.9177	***
DIST_EXP	9.1907	15.0449	***	5.3358	19.4243	***	4.5228	13.9932	***
Work and non-work accessibility									
DIST_CBD	-5.8059	-15.2880	***	-1.9542	-11.5005	***	-0.9550	-4.8406	***
DIST_SHOPPING	7.1168	13.6346	***	-0.9450	-4.0031	***	-0.6333	-2.2459	**
Neighborhood amenity									
MED_INC	-5.2436	-7.5432	***	-2.7222	-12.0766	***	-2.9737	-11.7488	***
POP_DENS	1.4903	2.5665	**	0.5167	2.0459	**	-3.2937	-10.3492	***
EMP_DENS	-1.7225	-2.8278	***	-1.1842	-10.8130	***	0.6019	5.4140	***
SCHOOL_DENS	-34.6578	-13.3966	***	1.3747	2.6697	***	6.6581	12.0732	***
Land attribute									
L_AROAD	0.9474	10.4469	***	0.5409	12.1259	***	-0.3133	-5.7257	***
LAND_PRICE	-0.8084	-10.6637	***	0.1176	3.2406	***	0.1033	2.4434	**
Rho-square (Nagelkerke)					0.2826				

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

4.7.1.5 Land Use Change Model of BTS Skytrain and MRT Blue Line

From Table 4 - 15, the equations of land use change along the BTS Skytrain and MRT Blue Line are shown as follows;

Residential: 5.264xDIST_BBSTA – 5.6514xDIST_MR + 9.1907xDIST_EXP – 0.8059xDIST_CBD + 7.1168xDIST_SHOPPING – 5.2436xMED_INC + 1.4903xPOP_DENS – 1.7225xEMP_DENS – 34.6578xSCHOOL_DENS + 0.9474xL_AROAD – 0.8084xLAND_PRICE

High-rise residential: – 4.3402xDIST_BBSTA – 14.3565xDIST_MR + 5.3358xDIST_EXP – 1.9542xDIST_CBD – 0.9450xDIST_SHOPPING – 2.7222xMED_INC + 0.5167xPOP_DENS – 1.1842xEMP_DENS + 1.3747xSCHOOL_DENS + 0.5409xL_AROAD + 0.1176xLAND_PRICE

Non-residential: – 1.3760xDIST_BBSTA – 16.3486xDIST_MR + 4.5228xDIST_EXP – 0.9550xDIST_CBD – 0.6333xDIST_SHOPPING – 2.9737xMED_INC – 3.2937xPOP_DENS + 0.6019xEMP_DENS + 6.6581xSCHOOL_DENS + 0.9474xL_AROAD – 0.8084xLAND_PRICE

4.7.2 Land Use Change Model: Airport Rail Link

Table 4 - 16 presents the land use change model for the adjacent area of the Airport Rail Link corridor which was calibrated by the multinomial logit model (ML). To capture the influencing factors in determining land use change model, the model results were estimated based on four categories including local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute. The goodness-of-fit is evaluated by Rho-square.

After extensive experimentations with different specifications, the model results were chosen based on the theoretical and statistical significance of the estimated parameters. The results of the final specification are discussed as below.

4.7.2.1 Effects of Local Transportation Accessibility

Local transportation accessibility variable refers to proximity to the rail transit station, main road and the expressway ramp (as in access ramp). First, the proximity to the nearest Airport Rail Link station (DIST_ASTA) has negative effect to the conversion of undeveloped to residential and high-rise residential uses meaning that land whose use changed from undeveloped to residential and high-rise residential uses is more likely to be near the Airport Rail Link station. On the other hand, land whose use changed from undeveloped to non-residential uses is less likely to be closer to the Airport Rail Link station. Not surprising, the probability of converting from undeveloped to residential, high-rise residential and non-residential uses was more likely to appear closer to main road. Next, distance to expressway access (DIST_EXP) has negative sign for the conversion of residential and high-rise residential uses, indicating that the distance to expressway increased the likelihood of conversions to residential and high-rise residential uses.

4.7.2.2 Effects of Work and Non-Work Accessibility

Work and non-work accessibility variable refers to proximity to the central business district where there are physically concentrated in the inner core of the Bangkok Metropolitan Region: Sukhumvit and Silom Area and another variable is the distance to the nearest shopping center or shopping mall. Not surprisingly, the distance to central business district (DIST_CBD) has positive sign for the three conversions, indicating that the distance to CBD did not increase the likelihood of conversions to each of the three land use conversion. Unlike, the likelihood of converting to residential, high-rise residential and non-residential uses occurred near the shopping center (DIST_SHP).

Table 4 - 16 Land Use Change Model: Airport Rail Link

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_ASTA	-1.8353	-9.1133	***	-4.0519	-5.6169	***	0.6648	2.6597	***
DIST_MR	-3.2519	-11.2733	***	-7.6296	-5.6822	***	-11.1816	-27.4331	***
DIST_EXP	-3.3935	-16.3359	***	-4.7281	-7.3231	***	1.7916	6.4809	***
Work and non-work accessibility									
DIST_CBD	1.0059	5.3475	***	11.0163	18.6200	***	0.4236	1.5187	n/s
DIST_SHOPPING	-2.1498	-12.4956	***	-6.2855	-9.9230	***	-2.3378	-8.7339	***
Neighborhood amenity									
MED_INC	-3.1660	-15.4694	***	-6.4323	-10.2126	***	-1.0616	-4.1082	***
POP_DENS	2.8885	9.6507	***	1.9173	1.2354	n/s	0.6001	0.8563	n/s
EMP_DENS	13.4543	17.3183	***	1.4724	0.5326	n/s	4.7724	3.8017	***
SCHOOL_DENS	-13.6257	-10.6555	***	19.9808	5.8357	***	-6.6591	-3.3425	***
Land attribute									
L_AROAD	0.4355	13.8846	***	-0.2305	-2.1367	**	0.9282	23.1053	***
LAND_PRICE	-5.0871	-35.4042	***	3.5483	7.9637	***	-1.8559	-8.8852	***
Rho-square (Nagelkerke)					0.1252				

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

4.7.2.3 Effects of Neighborhood Amenity

This variable includes the density of each zone (e.g. population per square kilometer, employment per square kilometer as well as student per square kilometer). First, the coefficient of median income variable has negative sign, suggesting that the lower income level, the more conversion they are. As population density surrounding an area grows, the probability of converting from undeveloped land to residential, high-rise residential and non-residential uses tended to increase. Likewise, employment density (EMP_DENS) was associated with a higher likelihood of land use conversion for all types of land use. Furthermore, the school density has positive coefficient, indicating that the greater number of school density increased the probability of converting from undeveloped land to high-rise residential uses.

4.7.2.4 Effects of Land Attribute

This variable includes the main road connection (L_AROAD) and land value (LAND_PRICE). Firstly, undeveloped land located in small road branching which connect to adjacent main roads was more likely to change to residential and non-residential uses. Higher land value is associated with the likelihood of conversion from undeveloped land to high-rise residential uses, while lower land value is greatly linked with the conversion of undeveloped land to residential and non-residential uses. This output confirms that more value land tends to be converted to intensified land uses, such as high-rise residential uses in this area.

4.7.2.5 Land Use Change Model of Airport Rail Link

From Table 4 - 16, the equations of land use changes along the Airport Rail Link are shown as follows;

Residential: – 1.8353xDIST_ASTA – 3.2519xDIST_MR – 3.3935xDIST_EXP + 1.0059xDIST_CBD – 2.1498xDIST_SHOPPING – 3.1660xMED_INC + 2.8885xPOP_DENS + 13.4543xEMP_DENS – 13.6257xSCHOOL_DENS + 0.4355xL_AROAD – 5.0871xLAND_PRICE

High-rise residential: – 4.0519xDIST_ASTA – 7.6296xDIST_MR – 4.7281xDIST_EXP + 11.0163xDIST_CBD – 6.2855xDIST_SHOPPING – 6.4323xMED_INC + 1.9173xPOP_DENS + 1.4724xEMP_DENS + 19.9808xSCHOOL_DENS – 0.2305xL_AROAD + 3.5483xLAND_PRICE

Non-residential: 0.6648xDIST_ASTA – 11.1816xDIST_MR + 1.7916xDIST_EXP + 0.4236xDIST_CBD – 2.3378xDIST_SHOPPING – 1.0616xMED_INC – 0.6001xPOP_DENS + 4.7724xEMP_DENS – 6.6591xSCHOOL_DENS + 0.9282xL_AROAD – 1.8559xLAND_PRICE

4.7.3 Land Use Change Model: MRT Purple Line

Table 4 - 17 presents the land use change model for the adjacent area of the MRT Purple Line corridor which was calibrated by the multinomial logit model (ML). To capture the influencing factors in determining land use change model, the model results were estimated based on four categories including local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute. The goodness-of-fit is evaluated by Rho-square.

After extensive experimentations with different specifications, the model results were chosen based on the theoretical and statistical significance of the estimated parameters. The results of the final specification are discussed as below.

Table 4 - 17 Land Use Change Model: MRT Purple Line

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_PSTA	8.5323	37.0256	***	-16.3465	-15.8197	***	2.1097	5.0572	***
DIST_MR	-2.0656	-9.3014	***	-12.8009	-10.5419	***	-25.7387	-39.9494	***
DIST_EXP	4.6043	17.1117	***	-8.3671	-8.9871	***	-2.3810	-6.7473	***
Work and non-work accessibility									
DIST_CBD	3.9368	34.9155	***	15.7043	19.1653	***	4.3391	17.3869	***
DIST_SHOPPING	-6.6444	-22.1756	***	3.2391	4.1925	***	2.1066	5.3988	***
Neighborhood amenity									
MED_INC	-0.0860	-2.6412	***	-31.2886	-19.7248	***	-1.9470	-3.1161	***
POP_DENS	0.2583	1.1424	n/s	-32.9652	-20.6308	***	-0.4208	-0.9221	n/s
EMP_DENS	-0.2934	-0.4777	n/s	123.5274	23.7457	***	10.0593	7.4090	***
SCHOOL_DENS	-7.4514	-4.3173	***	-384.1321	-22.3745	***	-50.0364	-8.9439	***
Land attribute									
L_AROAD	0.7926	24.3035	***	1.2307	12.5314	***	0.5354	8.9572	***
LAND_PRICE	1.1717	7.8187	***	-5.1240	-8.3198	***	3.0998	11.1145	***
Rho-square (Nagelkerke)					0.1380				

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

4.7.3.1 Effects of Local Transportation Accessibility

Local transportation accessibility variable refers to proximity to the rail transit station, main road and the expressway ramp (as in access ramp). First, the proximity to the nearest MRT Purple Line station (DIST_PSTA) has negative effect to the conversion of undeveloped to high-rise residential but positive effect to the conversion to residential and non-residential uses, meaning that land whose use changed from undeveloped to residential and non-residential uses is less likely to be near the MRT Purple Line station while the conversion to high-rise residential uses has emerged in areas closer to the station. Not surprising, the probability of converting from undeveloped to residential, high-rise residential and non-residential uses was more likely to appear closer to main road. Next, distance to expressway access (DIST_EXP) has positive sign for the conversion to residential uses but negative sign for high-rise residential and non-residential uses, indicating that the distance to expressway did not increase the likelihood of conversions to residential uses while high-rise residential and non-residential uses were found near the expressway access.

4.7.3.2 Effects of Work and Non-Work Accessibility

Work and non-work accessibility variable refers to proximity to the central business district where there are physically concentrated in the inner core of the Bangkok Metropolitan Region: Sukhumvit and Silom Area and another variable is the distance to the nearest shopping center or shopping mall. Not surprisingly, the conversion from undeveloped land to non-residential uses has emerged in area closer to the central business district (CBD) but land whose use changed from undeveloped to residential and non-residential uses is less likely to be near the CBD in term of straight-line distance. Furthermore, the likelihood of converting to residential occurred near the shopping center (DIST_SHP). Nevertheless, undeveloped land near the shopping center in this area is less likely to be converted to high-rise residential and non-residential uses.

4.7.3.3 Effects of Neighborhood Amenity

This variable includes the density of each zone (e.g. population per square kilometer, employment per square kilometer as well as student per square kilometer). First, the coefficient of median income variable has negative sign, suggesting that the lower income level, the more conversion they are. As population density surrounding an area grows, the probability of converting from undeveloped land to residential uses tended to increase. Employment density (EMP_DENS) was associated with a higher likelihood of land use conversion from undeveloped land to high-rise residential and non-residential uses. Nevertheless, the school density has positive coefficient, indicating that the greater number of school density decreased the probability of converting from undeveloped land to residential, high-rise residential and non-residential uses.

4.7.3.4 Effects of Land Attribute

This variable includes the main road connection (L_AROAD) and land value (LAND_PRICE). Firstly, undeveloped land located in small road branching which connect to adjacent main roads was more likely to change to residential, high-rise residential and non-residential uses. Lower land value is associated with the likelihood of conversions from undeveloped land to high-rise residential uses, while higher land value is greatly linked with the conversion of undeveloped land to residential and non-residential uses. This output confirms that more value land tends to be converted to intensified land uses, such as luxury residential and non-residential uses.

4.7.3.5 Land Use Change Model of MRT Purple Line

From Table 4 - 17, the equations of land use changes along the MRT Purple Line are shown as follows;

Residential: 8.5323xDIST_PSTA – 2.0656xDIST_MR + 4.6043xDIST_EXP + 3.9368xDIST_CBD – 6.6444xDIST_SHOPPING - 0.0860xMED_INC + 0.2583xPOP_DENS – 0.2934xEMP_DENS – 7.4514xSCHOOL_DENS + 0.7926xL_AROAD – 1.1717xLAND_PRICE

High-rise residential: – 16.3465xDIST_PSTA – 12.8009xDIST_MR – 8.3671xDIST_EXP + 15.7043xDIST_CBD + 3.2391xDIST_SHOPPING – 31.2886xMED_INC – 32.9652xPOP_DENS + 123.5274xEMP_DENS – 384.1321xSCHOOL_DENS – 1.2307xL_AROAD – 5.1240xLAND_PRICE

Non-residential: 2.1097xDIST_PSTA – 25.7387xDIST_MR – 2.3810xDIST_EXP + 4.3391xDIST_CBD + 2.1066xDIST_SHOPPING – 1.9470xMED_INC – 0.4208xPOP_DENS + 10.0593xEMP_DENS – 50.0364xSCHOOL_DENS + 0.5354xL_AROAD + 3.0998xLAND_PRICE

4.8 Effects of Urban Rail Transit Investment on Land Use Change

This section intends to measure of effects of urban rail transit infrastructure in studies of land use conversions. In the context of this section, wider benefits refer to the benefits beyond the geographic region in which the urban rail transit development is undertaken. Since capitalization effects were thought to vary by urban rail transit corridor, the analysis in this section will be stratified to measures difference in land use change impacts for the three existing urban rail transit in Bangkok Metropolitan region: BTS Skytrain, MRT Blue Line and Airport Rail Link and for under construction line: MRT Purple Line.

To measure the capitalization effects of urban rail transit investment, the effects of the relative influence of proximity to each urban rail transit by exposing the coefficients used with each dummy variable for straight line distance intervals to the existing rail transit system: BTS Skytrain, MRT Blue Line and Airport Rail Link and under construction line: MRT Purple Line. The capitalization effects of residential, high-rise residential and non-residential land uses are presented in Table 4 - 18 to Table 4 - 20. The table estimate all variables used in the previous section in order to controlling the effects of urban rail transit and other factors.

In addition, from Table 4 - 18 to Table 4 - 20, the equations of land use changes by distance intervals among urban rail transit lines can be written as follows;

For BTS Skytrain and MRT Blue Line:

Residential: – 0.0094xDIST_BBSTA0.4 – 0.3732xDIST_BBSTA0.8 – 0.8847xDIST_BBSTA1.2 + 0.0783xDIST_BBSTA1.6 + 0.4334xDIST_BBSTA2 – 6.3473xDIST_MR + 8.4840xDIST_EXP + 7.1790xDIST_CBD – 5.3210xDIST_SHOPPING – 1.5775xMED_INC + 1.5775xPOP_DENS – 1.7673xEMP_DENS – 34.2392xSCHOOL_DENS + 0.9124xL_AROAD – 0.8538xLAND_PRICE

High-rise residential: 1.7321xDIST_BBSTA0.4 + 1.4425xDIST_BBSTA0.8 + 0.8671xDIST_BBSTA1.2 + 0.8435xDIST_BBSTA1.6 +1.2850xDIST_BBSTA2 – 14.2698xDIST_MR + 5.2024xDIST_EXP – 2.1593xDIST_CBD – 0.6697xDIST_SHOPPING – 2.4851xMED_INC + 0.2539xPOP_DENS – 1.2873xEMP_DENS + 1.1555xSCHOOL_DENS + 0.5584xL_AROAD + 0.0942xLAND_PRICE

Non-residential: 0.1385xDIST_BBSTA0.4 – 0.7432xDIST_BBSTA0.8 – 1.0809xDIST_BBSTA1.2 – 0.9710xDIST_BBSTA1.6 – 1.4925xDIST_BBSTA2 – 11.8618xDIST_MR + 4.7938xDIST_EXP – 1.3916xDIST_CBD + 0.1500xDIST_SHOPPING – 1.8750xMED_INC – 3.7547xPOP_DENS + 0.4992xEMP_DENS + 7.0814xSCHOOL_DENS – 0.3477xL_AROAD + 0.0599xLAND_PRICE

Table 4 - 18 Land Use Change Model by Distance Intervals: BTS Skytrain and MRT Blue Line Station

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_BBSTA0.4	-0.0094	-0.0464	n/s	1.7321	12.6698	***	0.1385	1.3183	n/s
DIST_BBSTA0.8	-0.3732	-2.4031	**	1.4425	10.9361	***	-0.7432	-7.4530	***
DIST_BBSTA1.2	-0.8847	-5.9954	***	0.8671	6.5955	***	-1.0809	-11.1195	***
DIST_BBSTA1.6	0.0783	0.6981	n/s	0.8435	6.3046	***	-0.9710	-9.8019	***
DIST_BBSTA2	0.4334	4.1158	***	1.2850	9.0077	***	-1.4925	-11.9433	***
DIST_MR	-6.3473	-7.7907	***	-14.2698	-20.9130	***	-11.8618	-14.7736	***
DIST_EXP	8.4840	13.6772	***	5.2024	18.6689	***	4.7938	14.5445	***
Work and non-work accessibility-									
DIST_CBD	7.1790	-15.2126	***	-2.1593	-12.4320	***	-1.3916	-6.8353	***
DIST_SHOPPING	-5.3210	13.2201	***	-0.6697	-2.7783	***	0.1500	0.5278	n/s
Neighborhood amenity									
MED_INC	-1.5775	-7.6544	***	-2.4851	-10.5704	***	-1.8750	-7.0556	***
POP_DENS	1.5775	2.6644	***	0.2539	0.9769	n/s	-3.7547	-11.6483	***
EMP_DENS	-1.7673	-2.9257	***	-1.2873	-11.5247	***	0.4992	4.3662	***
SCHOOL_DENS	-34.2392	-13.3783	***	1.1555	2.2078	**	7.0814	12.5023	***
Land attribute									
L_AROAD	0.9124	9.9885	***	0.5584	12.3276	***	-0.3477	-6.2282	***
LAND_PRICE	-0.8538	-11.1781	***	0.0942	2.5824	**	0.0599	1.3848	n/s
Rho-square (Nagelkerke)					0.3080				

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 4 - 19 Land Use Change Model by Distance Intervals: Airport Rail Link Station

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_ASTA0.5	-17.7692	-0.0231	n/s	-15.9409	-0.0056	n/s	-0.8340	-7.7223	***
DIST_ASTA1	1.2336	17.8227	***	2.6077	7.8367	***	-0.9558	-12.9986	***
DIST_ASTA1.5	0.4087	5.9205	***	1.4895	4.5362	***	-1.1833	-16.8324	***
DIST_ASTA2	1.1572	18.8467	***	2.6952	8.6689	***	-0.4754	-7.8720	***
DIST_ASTA2.5	0.6446	10.5047	***	1.0933	3.3498	***	-1.2911	-20.3431	***
DIST_ASTA3	0.7196	12.3080	***	1.2258	3.9239	***	-1.1992	-19.8291	***
DIST_MR	-3.4218	-11.7860	***	-6.8527	-4.8899	***	-13.3631	-31.7728	***
DIST_EXP	-3.2143	-14.9639	***	-6.6875	-9.3429	***	2.4245	8.7170	***
Work and non-work accessibility									
DIST_CBD	1.2490	6.4253	***	11.4329	18.5306	***	-0.1361	-0.4830	n/s
DIST_SHOPPING	-2.3910	-13.9074	***	-5.7078	-9.2099	***	-2.0020	-7.3194	***
Neighborhood amenity									
MED_INC	-3.4513	-16.5457	***	-6.6962	-10.3730	***	0.3796	1.3992	n/s
POP_DENS	2.7623	9.0312	***	0.7270	0.4478	n/s	2.4724	3.4660	***
EMP_DENS	12.9223	16.5171	***	1.9371	0.7282	n/s	0.1467	0.1111	n/s
SCHOOL_DENS	-11.2224	-8.7675	***	18.4210	5.4339	***	-12.9689	-6.2632	***
Land attribute									
L_AROAD	0.5302	16.3715	***	-0.0223	-0.1995	n/s	0.7798	18.0069	***
LAND_PRICE	-4.9108	-34.3272	***	2.5985	5.6846	***	-1.0876	-5.1182	***
Rho-square (Nagelkerke)					0.1592				

*** = significant at 1% level
** = significant at 5% level
* = significant at 10% level
n/s = no significant

Table 4 - 20 Land Use Change Model by Distance Intervals: MRT Purple Line Station

Variables	Residential Uses			High-Rise Residential Uses			Non-Residential Uses		
	Parameter	t-Statistic		Parameter	t-Statistic		Parameter	t-Statistic	
Local transportation accessibility									
DIST_PSTA0.25	-1.9165	-17.0541	***	2.9393	7.5017	***	0.4362	5.1444	***
DIST_PSTA0.5	-1.2555	-25.2399	***	3.7819	12.5787	***	-0.9518	-11.9726	***
DIST_PSTA0.75	-0.6727	-16.0587	***	3.4574	11.6706	***	-0.4713	-6.2939	***
DIST_PSTA1	-0.7096	-18.3337	***	4.0241	14.4565	***	-1.2498	-15.2767	***
DIST_PSTA1.25	-0.8073	-22.6062	***	3.7401	14.0537	***	-1.0850	-14.0775	***
DIST_PSTA1.5	-0.0509	-1.6232	n/s	0.8107	2.3729	**	-0.2058	-2.8031	***
DIST_PSTA1.75	0.2567	8.5588	***	1.3294	4.3571	***	-0.2052	-2.8300	***
DIST_MR	-1.6593	-7.6833	***	-9.4628	-7.0303	***	-24.8669	-39.4687	***
DIST_EXP	3.9386	14.9778	***	-9.0647	-8.2434	***	-1.0209	-2.8675	***
Work and non-work accessibility									
DIST_CBD	3.0666	27.1502	***	15.2228	18.0077	***	4.0589	16.0029	***
DIST_SHOPPING	-5.1104	-17.7432	***	4.0275	4.5940	***	1.0729	2.6533	***
Neighborhood amenity									
MED_INC	-1.3214	-4.0554	***	-29.7984	-19.3741	***	0.2900	0.4548	n/s
POP_DENS	-0.4401	-1.9509	*	-29.9676	-20.5437	***	1.8674	3.8810	***
EMP_DENS	1.9057	3.0940	***	114.7467	23.1448	***	9.2333	6.4668	***
SCHOOL_DENS	-9.0803	-5.5375	***	-349.6563	-20.6345	***	-62.9621	-9.8625	***
Land attribute									
L_AROAD	0.9288	27.8521	***	0.8969	8.6630	***	0.6302	0.6302	n/s
LAND_PRICE	0.7767	5.1736	***	-6.3540	-10.4711	***	4.6860	4.6860	***
Rho-square (Nagelkerke)					0.1622				

*** = significant at 1% level
** = significant at 5% level
* = significant at 10% level
n/s = no significant

For Airport Rail Link:

Residential: – 17.7692xDIST_ASTA0.5 + 1.2336xDIST_ASTA1 + 0.4087xDIST_ASTA1.5 + 1.1572xDIST_ASTA2 + 0.6446xDIST_ASTA2.5 + 0.7196xDIST_ASTA3 – 3.4218xDIST_MR – 3.2143xDIST_EXP + 1.2490xDIST_CBD – 2.3910xDIST_SHOPPING – 3.4513xMED_INC + 2.7623xPOP_DENS + 12.9223xEMP_DENS – 11.2224xSCHOOL_DENS + 0.5302xL_AROAD – 4.9108xLAND_PRICE

High-rise residential: – 15.9409xDIST_ASTA0.5 + 2.6077xDIST_ASTA1 + 1.4895xDIST_ASTA1.5 + 2.6952xDIST_ASTA2 + 1.0933xDIST_ASTA2.5 + 1.2258xDIST_ASTA3 – 6.8527xDIST_MR – 6.6875xDIST_EXP + 11.4329xDIST_CBD – 5.7078xDIST_SHOPPING – 6.6962xMED_INC + 0.7270xPOP_DENS + 1.9371xEMP_DENS + 18.4210xSCHOOL_DENS – 0.0223xL_AROAD – 2.5985xLAND_PRICE

Non-residential: – 0.8340xDIST_ASTA0.5 – 0.9558xDIST_ASTA1 – 1.1833xDIST_ASTA1.5 – 0.4754xDIST_ASTA2 – 1.2911xDIST_ASTA2.5 – 1.1992xDIST_ASTA3 – 13.3631xDIST_MR + 2.4245xDIST_EXP – 0.1361xDIST_CBD – 2.0020xDIST_SHOPPING + 0.3796xMED_INC + 2.4724xPOP_DENS + 0.1467xEMP_DENS – 12.9689xSCHOOL_DENS + 0.7798xL_AROAD – 1.0876xLAND_PRICE

For MRT Purple Line:

Residential: – 1.9165xDIST_PSTA0.25 – 1.2555xDIST_ PSTA0.5 – 0.6727xDIST_PSTA0.75 – 0.7096xDIST_PSTA1 – 0.8073xDIST_PSTA1.25 – 0.0509xDIST_PSTA1.5 + 0.2567xDIST_PSTA1.75 – 1.6593xDIST_MR + 3.9386xDIST_EXP + 3.0666xDIST_CBD – 5.1104xDIST_SHOPPING – 1.3214xMED_INC – 0.4401xPOP_DENS + 1.9057xEMP_DENS – 9.0803xSCHOOL_DENS + 0.9288xL_AROAD + 0.7767xLAND_PRICE

High-rise residential: 2.9393xDIST_PSTA0.25 + 3.7819xDIST_ PSTA0.5 + 3.4574xDIST_PSTA0.75 + 4.0241xDIST_PSTA1 + 3.7401xDIST_PSTA1.25 + 0.8107xDIST_PSTA1.5 + 1.3294xDIST_PSTA1.75 – 9.4628xDIST_MR – 9.0647xDIST_EXP + 15.2228xDIST_CBD + 4.0275xDIST_SHOPPING – 29.7984xMED_INC – 29.9676xPOP_DENS + 114.7467xEMP_DENS – 349.6563xSCHOOL_DENS + 0.8969xL_AROAD – 6.3540xLAND_PRICE

Non-residential: 0.4362xDIST_PSTA0.25 – 0.9518xDIST_ PSTA0.5 – 0.4713xDIST_PSTA0.75 – 1.2498xDIST_PSTA1 – 1.0850xDIST_PSTA1.25 – 0.2058xDIST_PSTA1.5 – 0.2052xDIST_PSTA1.75 – 24.8669xDIST_MR – 1.0209xDIST_EXP + 4.0589xDIST_CBD + 1.0729xDIST_SHOPPING + 0.2900xMED_INC + 1.8674xPOP_DENS + 9.2333xEMP_DENS – 62.9621xSCHOOL_DENS + 0.6302xL_AROAD + 4.6860xLAND_PRICE

4.8.1 Effects of Urban Rail Transit on Land Use Change by Distance Intervals: BTS Skytrain and MRT Blue Line

Controlling the other predictors, Figure 4 - 8 presents the effects of land use change being converted near the stations of BTS Skytrain and MRT Blue Line. The distance ring that provides the best statistical fits is the distance to the stations within 2 kilometers. The figure illustrates the types of land use conversions between 2004 and 2010: from undeveloped to residential uses (blue bar), to high-rise residential uses (red bar) and to non-residential uses (green bar).

Due to the extreme competition among residential, high-rise residential and non residential land uses surrounding the BTS Skytrain and MRT Blue Line corridor, the switch from undeveloped to residential uses (e.g., attached housing, detached housing, etc.) has occurred in the areas farther away than 1.2 kilometers from the BTS Skytrain and MRT Blue Line corridor. Conversely, the likelihood of changing from undeveloped land to high-rise residential uses (e.g. condominium and apartment) was found within 0 to 2 kilometers. Lastly, the conversion of undeveloped land to non-residential uses (e.g. office buildings, commercial uses, etc.) has emerged within 0 to 400 meters from the corridor. It is notably that the conversions of land from undeveloped to non-residential uses are weaker than the likelihood of conversion of undeveloped to high-rise residential uses. The overall patterns in land use change summarize the rise of high-rise residential and non-residential uses near the corridor while residential land uses mainly located 1.2 kilometers farther from the corridor. High-rise residents and office workers can enjoy the urban rail transit amenities and retail owners can attract customers who visit the along the corridor.

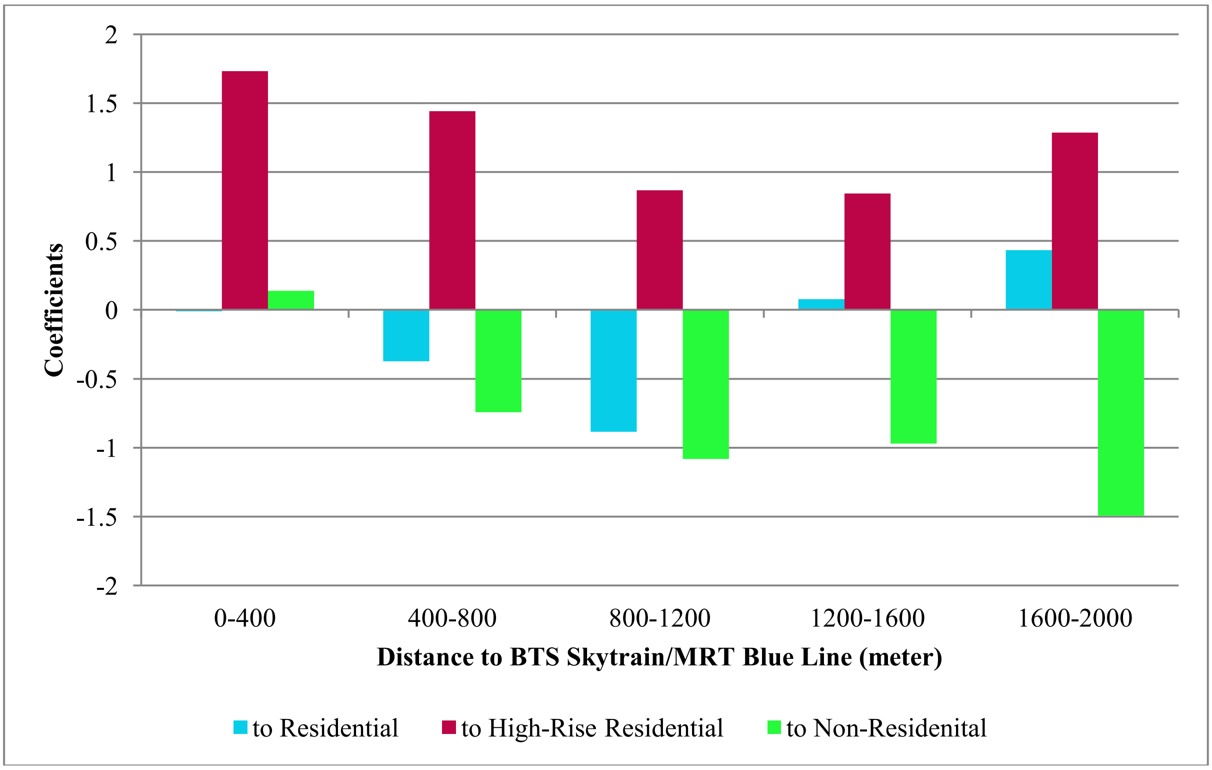

Figure 4 - 8 Coefficient Effects of Urban Rail Transit on Land Use Change by Distance Intervals along BTS Skytrain and MRT Blue Line

4.8.2 Effects of Urban Rail Transit on Land Use Change by Distance Intervals: Airport Rail Link

Figure 4 - 9 presents the effects of land use change being converted near the stations of Airport Rail Link. The distance ring that provides the best statistical fits is the distance to the stations within 3 kilometers. The figure illustrates the types of land use conversions between 2004 and 2010: from undeveloped to residential uses (blue bar), to high-rise residential uses (red bar) and to non-residential uses (green bar).

Among surrounding the Airport Rail Link corridor, the switch from undeveloped to residential uses (e.g., attached housing, detached housing, etc.) has occurred in the areas within 500 meters to 3 kilometers from the Airport Rail Link corridor. Likewise, the likelihood of changing from undeveloped land to high-rise residential uses (e.g. condominium and apartment) was found from 500 meters to 3 kilometers. However, the conversions of land from undeveloped to residential uses are weaker than the likelihood of conversion of undeveloped to high-rise residential uses. Lastly, the conversion of undeveloped land to non-residential uses (e.g. warehouses, factories, etc.) has emerged in the areas farther away than 3 kilometers from the Airport Rail Link corridor. The overall patterns in land use change summarize the rise of residential and high-rise residential uses near the corridor while non-residential land uses mainly located 3 kilometers farther from the corridor. Residents and high-rise residents can enjoy the urban rail transit amenities but the effect of distance to urban rail transit cannot attract warehouse and factory owners along the corridor.

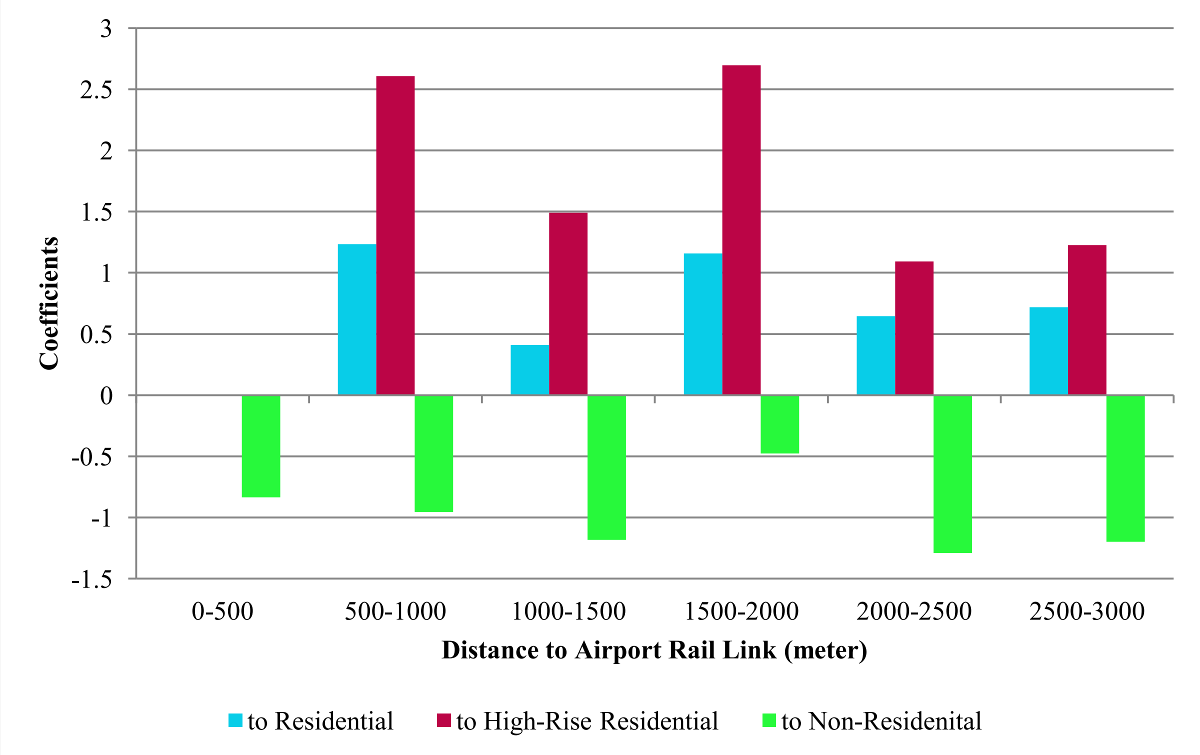

Figure 4 - 9 Coefficient Effects of Urban Rail Transit on Land Use Change by Distance Intervals along Airport Rail Link

4.8.3 Effects of Urban Rail Transit on Land Use Change by Distance Intervals: MRT Purple Line

Figure 4 - 10 presents the effects of land use change being converted near the stations of Airport Rail Link. The distance ring that provides the best statistical fits is the distance to the stations within 2 kilometers. The figure illustrates the types of land use conversions between 2004 and 2010: from undeveloped to residential uses (blue bar), to high-rise residential uses (red bar) and to non-residential uses (green bar).

Among residential, high-rise residential and non residential land uses surrounding the MRT Purple Line corridor, the switch from undeveloped to residential uses (e.g., attached housing, detached housing, etc.) has occurred in the areas farther away from the MRT Purple corridor approximately 1.5 kilometers. Conversely, the likelihood of changing from undeveloped land to high-rise residential uses (e.g. condominium and apartment) was found within 2 kilometers. Lastly, the conversion of undeveloped land to non-residential uses (e.g. shop, warehouses, etc.) has emerged in the areas within 250 meters from the MRT Purple Line corridor. The overall patterns in land use change summarize the rise of high-rise residential and non-residential uses near the corridor while residential uses mainly located 1.5 kilometers farther from the corridor or more. High-rise residents can enjoy the urban rail transit amenities but the effect of distance to urban rail transit cannot attract residents and shop and warehouse owners along the corridor.

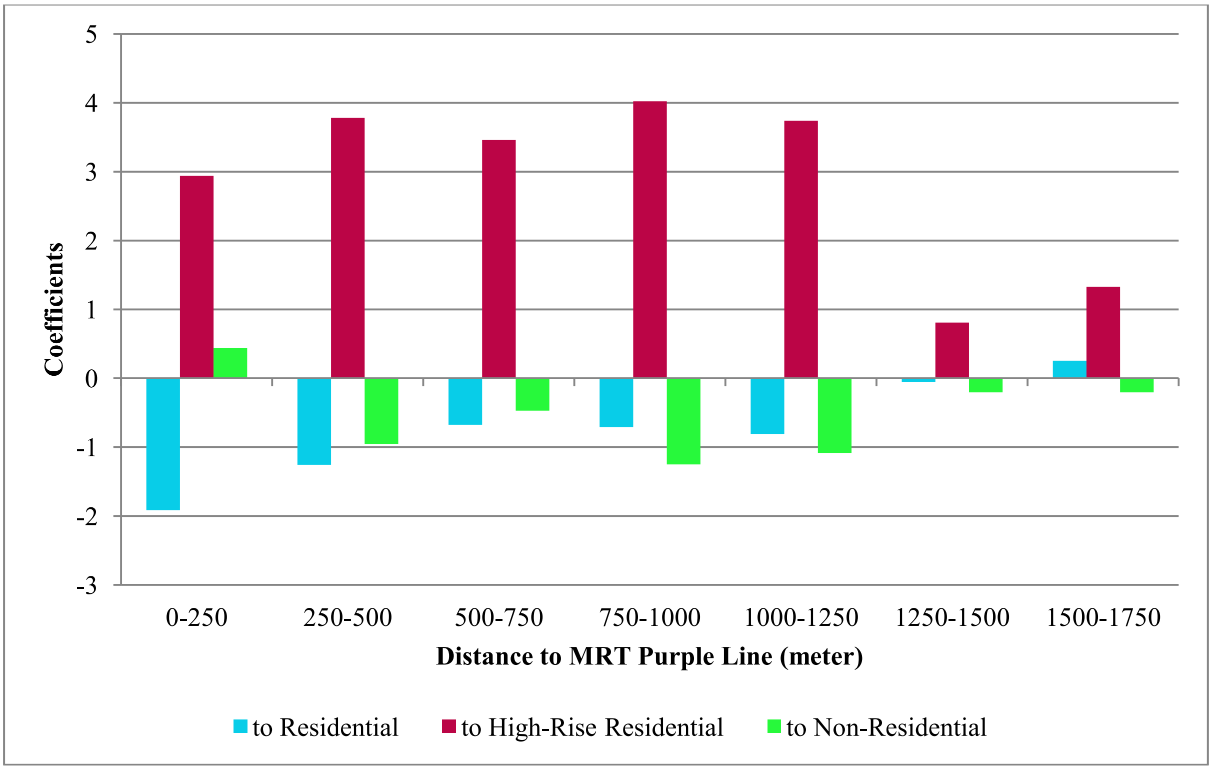

Figure 4 - 10 Coefficient Effects of Urban Rail Transit on Land Use Change by Distance Intervals along MRT Purple Line

4.9 Summary

This section summarizes the findings from the land use change models as a result of urban rail transit development. Land use change models obtained from the conversions of land along the three existing urban rail transit (i.e., BTS Skytrain, MRT Blue Line and Airport Rail Link) and another one from under construction line (i.e., MRT Purple Line). However, the land use change data along the BTS Skytrain and MRT Blue Line was examined together due to the spatial location and started service time period. On the other hand, the conversions along the Airport Rail Link and MRT Purple Line were investigated separately. Land use types were classified into three categories: residential uses (e.g. attached housing, detached housing, semi-detached housing, etc.), high-rise residential uses (e.g. condominium and apartment) and non-residential uses (e.g. commercial, office building, retail shop, warehouse, factory, etc).

As known, factors influencing land use change are myriad. One of the objective in this chapter focuses on the influencing factors in determining land use conversions. The important findings from the empirical analysis are as follows. First, local transportation accessibility does affect land use changes. For example, the models confirm the greater influencing of the proximity to main road, i.e., the closer to the main road, the probability of conversion intended to increase especially for non-residential uses and followed by high-rise residential uses. This result might reflect the situation of the accessibility to transportation and poor land planning. In addition, many land development occur in the many small streets which branch off the main road but feeders mode to main road is not efficiency and inadequate. Therefore, land parcels closer to the main road attract developers than those located farther away. Although the proximity to main road is significantly associated with the conversions for all categories in all areas, distance to expressway access is the dominant factor for the conversions especially to residential uses in the outer areas, i.e., the areas along Airport Rail Link and MRT Purple Line but the conversions were less likely to be near distance to expressway access in the areas along BTS Skytrain and MRT Blue Line which mainly served in the city. This claims that expressway network is still important for people who live in the outer areas and use private car for travel ahead to the city so as to increase travel speed and decrease travel time. Further, the conversion from undeveloped land to high-rise residential and non-residential uses has emerged in the areas closer to the central business district (CBD). As the distance to shopping center decreases, the probability of converting from undeveloped land to residential uses tends to increases in the areas along the Airport Rail Link and MRT Blue Line. Among the neighborhood amenity variables, they are also related to the conversions of land use however they occurred spatially differentiate. Higher land value is associated with the likelihood of conversions from undeveloped land to high-rise residential and non-residential uses, while lower land value is greatly linked with the conversion of undeveloped land to residential uses. This output confirms that more value land tends to be converted to intensified land uses, such as luxury high-rise residential and high-end non-residential uses.

Next, another objective of this chapter is to investigate the effects of urban rail transit on land use change. Land use change models confirm that conversion of land for residential uses is more likely to emerge within the 1.2 kilometers to 2 kilometer of the BTS Skytrain and MRT Blue Line stations but within 500 meters to 3 kilometers of the Airport Rail Link and more than 1.5 kilometers of the MRT Purple Line while the likelihood of changing from undeveloped land to high-rise residential uses was found within 2 kilometers from the BTS Skytrain and MRT Blue Line stations similar to the land conversion along the MRT Purple Line, and within 500 meters to 3 kilometers from the Airport Rail Link. These results indicated that the probability of converting from undeveloped to high-rise residential was found closer to the stations than the conversion to residential uses. This suggests that people who prefer living in condominium and apartment were attracted by the proximity to the urban rail transit stations, i.e., easy access to the station with the shortest time. Furthermore, among the extreme competition in each land use category located in each area, the likelihood of conversion to residential uses in the areas along the Airport Rail Link is stronger than other area, the probability of converting to high-rise residential uses in the adjacent areas of the BTS Skytrain and MRT Blue Line and the Airport Rail Link is quite similar but found the higher probability of land conversion to high-rise residential along the MRT Purple Line even if it is now under construction. Next, the likelihood of changing from undeveloped land to non-residential uses increased only within 400 meters of the BTS Skytrain. In the adjacent areas of the BTS Skytrain and MRT Blue line, non-residential uses was focused in viewpoint of commercial uses such as office building, shopping mall, shop store, luxury hotel, etc. As the distance to stations decreases, they can get more an attractive to visit by customers due to the convenient. However, this effect was not found within 3 kilometer of the Airport Rail Link. As mentioned, non-residential uses along the Airport Rail Link are warehouses and factories. This kind of non-residential uses might not associate with the likelihood of conversion occurred near the stations. Besides, the conversion of undeveloped to non-residential uses was more likely to be near the stations of MRT Purple Line, only within 250 meters.

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CHAPTER 5

HOW DOES THE EFFECT OF URBAN RAIL TRANSIT DEVELOPMENT INFLUENCE ON LAND PRICE

The urban rail transit investment effects on land development and increases in property value are well recognized in developed countries but less investigated in developing countries. This chapter has the ultimate goal of examining the extent of the influence of rail transit investment in the context of land price in developing countries. Specifically, this study determines the spatial variation of the relationship between land price, and its attributes and accessibility to transit service. A global regression framework is applied to determine the value of land based on its attributes. The global regression assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, the variations of the influences on the land value are revealed by classifying data into different groups of land use such as residential and non-residential and incorporating spatial heterogeneity. The spatial statistical test is based on the geographically weighted regression model (GWR) that allows estimating a model at each observation point. The global regression model showed a significant correlation between land prices and its attributes and accessibility to transit service. However, the GWR model provided a better fit and revealed that rail transit has a positive impact on land price in some areas but negative in others. The increases in private land values generated by public investment such as rail transit development have been expected by developers. This benefit will be definitely reflected to the more than 10 transit lines that are planned for construction in the future. Understanding those impacts is necessary in order to allow the public agencies to tax the direct beneficiaries of their investments in the affected districts in advance so as to finance infrastructure projects

5.1 Background and Motivation

Since the structure and capacity of rail transit networks affect the level of accessibility. The adjacent areas of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become the attractiveness areas for land development, e.g., residential and commercial development. With high demand for sites that offer good rail transit opportunities, it is in turn lead to increased land price as competition. If this true, such sites will be able to offer high price.

Previous study (Vichiensan *et al.*, 2007) showed that land price has remarkably increased around the rail transit stations by a contour plot of change of the official land value assessment during the year 1992 and 2006 as discussed in Chapter 2, however, to what extent it has influence over space is still questionable. This Chapter has the ultimate goal of examining the extent of the influence of urban rail transit investment in the context of land price. Specifically, the study determines the spatial variation of the relationship between land price and its attributes in view point of benefits of urban rail transit investment. The case study is an area of Bangkok Metropolitan Region which is Bangkok's the first, second and third urban rail transit having been in service for around 13, 9 and 4 years, respectively. These areas along the corridors have undergone rapid land development, reflecting on the studies of land use changes in Chapter 4. Furthermore, even if many previous studies (Cervero and Duncan, 2004; Clower and Weinstein, 2002; Hess and Almeida, 2007; Yan *et al.*, 2012), experienced in developed countries, summarized and interpreted the relationship between land price or property value and transportation investments, it is, in particular, has not been well investigated in developing countries.

Such understanding the impacts is necessary for integrating the impacts of transportation system development especially urban rail transit system into the transportation and urban planning policy in order to allow the government to finance infrastructure projects by selling land in the affected districts in advance.

5.2 Objective and Approach

The main objective of this chapter aims to examine the effects of urban rail transit in term of benefits of investment on land price as well as its spatial variation in Bangkok Metropolitan Region. I hypothesize that urban rail transit investment changes location accessibility of properties that attract the developers with incentives to convert properties to more profitable and denser uses which in turn lead to increase land price.

In an ideal experimental situation, I would test my hypothesis using the same sites with the same set of land parcels, compare the effects before introduce urban rail transit to those sites and after started full of operation. However, this experimental technique is not possible due to lacking the data. Thus, I estimate the effects of urban rail transit on each land parcel by conducting a match pairs test with the effects of other transport infrastructure, i.e., the proximity to main road.

To fulfill the objective of this chapter, the overall process is to be followed as below.

- First step investigates the change in land price along the urban rail transit corridors by comparing appreciated land value before introduce urban rail transit and after open its service.

- Second step examines the factors that determine the land price of each parcel using hedonic analysis (e.g. global regression and local regression) at the metropolitan scale, that is, the extent of the metropolitan areas.

- Third step considers the role of urban rail transit in term of benefits of investment compared with the major role of main road.

The rest of this chapter is organized as follows. The next section explains data collection and variable specifications. Then, the descriptive statistics in order to explain the differences of land price and other factors among land use pattern groups will be presented. Then, regression model and regression model with structuralized spatial effects are applied to estimate the land price impacts of urban rail transit development.

5.3 Data Collection

The Bangkok Metropolitan Region of Thailand illustrated in Figure 5 - 1 is selected as a case study. Since it is an empirical study, it is necessary to collect several data from various sources. Among various types of required data, land price data used to carry out was obtained from the assessed land value reports, which were published by The Treasury Department, Thailand. This report generally uses to determine the property taxes for local government. The period time of this land value report had employed to capture taxes during the year 2008 to 2011 (assume the same land value for 4 years); however, it was evaluated before published around 2 years, i.e., this assessed value had started evaluated since 2006 and published in the year 2008. The sample of land price data is shown in Figure 5 - 2. In addition, the assessed land value is an unrealistic value. In the other word, it often too low, but sometimes high; however, it often bears relationship to the real value of property. Although the assessed land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand.

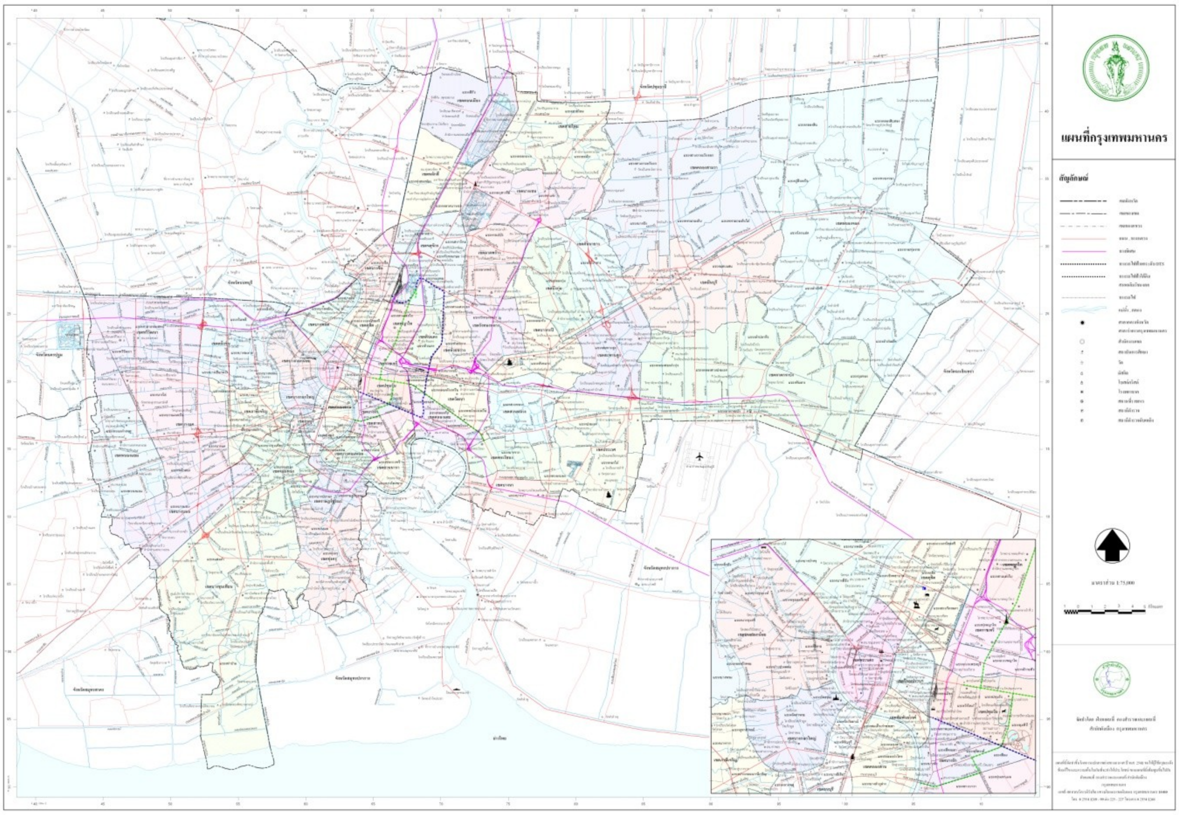

Figure 5 - 1 Catchment Area of Land Price Study

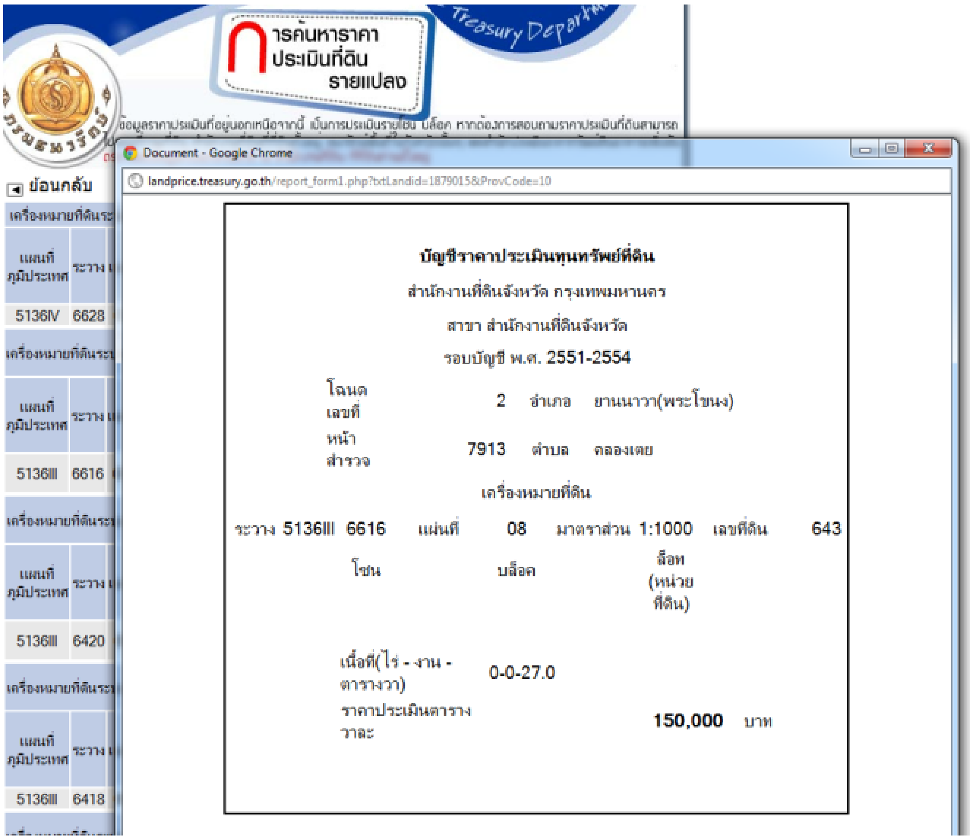

Figure 5 - 2 Sample of Obtained Data
Source: www. treasury.go.th data only available in Thai

After obtained the land price data, I used the data base of Land Department, Thailand (Figure 5 - 3) in order to check the universal Transverse Mercator (UTM) coordinate system of each land parcel and then Geographic Information System (GIS) was used to plot the sites.

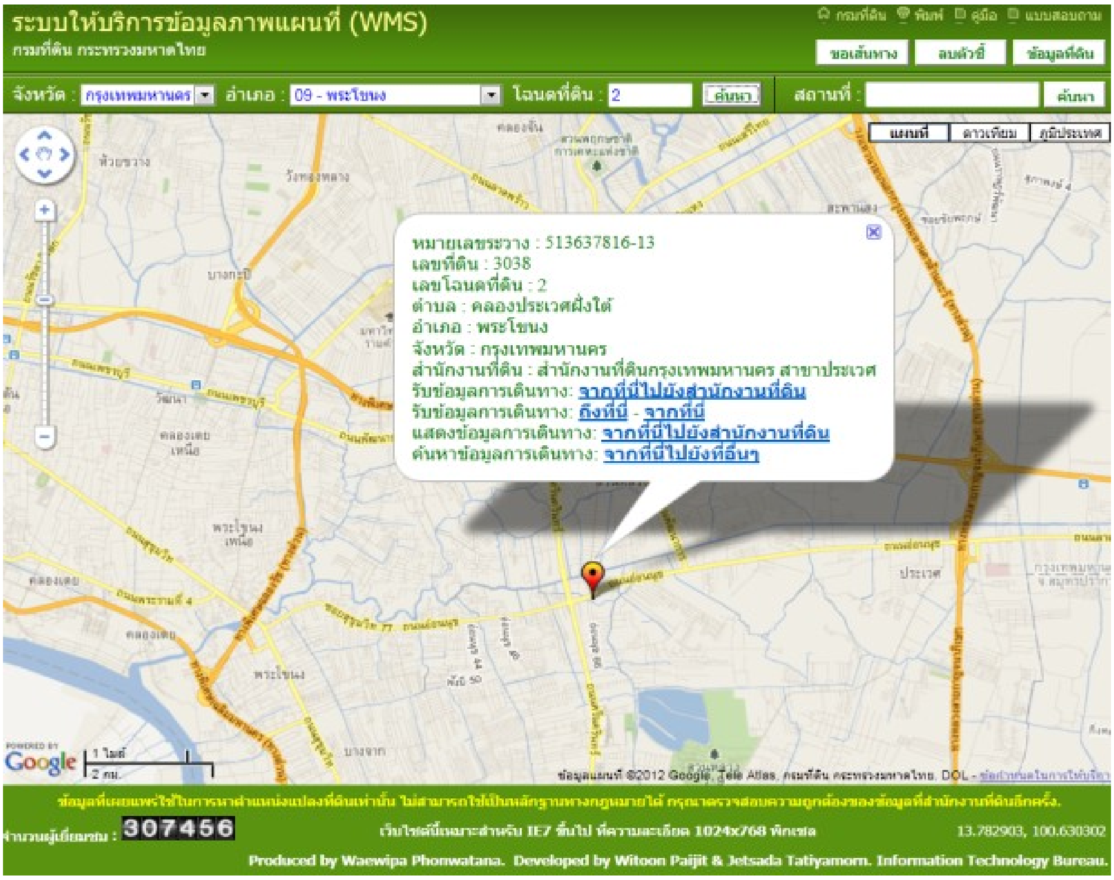

Figure 5 - 3 Data Base Web Check of Land Department
Source: www. dolwms.dol.go.th

Furthermore, the variations of the influences on the land price are clearly revealed by considering different groups of land use features. More specifically, among observed data are groups into two categories: residential land uses and non-residential land uses. For this study, undeveloped land often uses to indicate the vacant land and agriculture uses. The residential land cover is a type of land use where the predominant use is housing. The composition of land use among residential parcels is as follows: single-family housing, multi-family housing (twin house, townhouse, and row house), and high-rise building for residence (condominium, apartment, and flat). Finally, the non-residential land use is a type of land use where predominate use is not for dwelling purpose (commercial-retail and office building).

In order to examine the effect of urban rail transit development on land price, I measured the capitalization effect for each existing urban rail transit network separately: BTS Skytrain, MRT Blue Line and Airport Rail Link using the marginal effect.

5.4 Variable Specifications

Table 5 - 1 and Table 5 - 2 provide variable description and data sources that were used to estimate. Based on past studied, four types of information were used as independent variables: local transportation accessibility, work and non-work accessibility, neighborhood amenity as well as land attribute.

Table 5 - 1 Variables Description and Data Sources for Residential Land Price

Variables	Description	Data Source
Local transportation accessibility		
DIST_STA	Distance to nearest station (km)	Calculated using GIS
DIST_GSTA0.5	Dummy variable (set 1, if distance to BTS Skytrain ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_GSTA1.0	Dummy variable (set 1, if 0.5km < distance to BTS Skytrain ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_GSTA1.5	Dummy variable (set 1, if 1.0km < distance to BTS Skytrain ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_GSTA2.0	Dummy variable (set 1, if 1.5km < distance to BTS Skytrain ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_BSTA0.5	Dummy variable (set 1, if distance to MRT Blue Line ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_BSTA1.0	Dummy variable (set 1, if 0.5km < distance to MRT Blue Line ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_BSTA1.5	Dummy variable (set 1, if 1.0km < distance to MRT Blue Line ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_BSTA2.0	Dummy variable (set 1, if 1.5km < distance to MRT Blue Line ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_ASTA0.5	Dummy variable (set 1, if distance to Airport Rail Link ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_ASTA1.0	Dummy variable (set 1, if 0.5km < distance to Airport Rail Link ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_ASTA1.5	Dummy variable (set 1, if 1.0km < distance to Airport Rail Link ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_ASTA2.0	Dummy variable (set 1, if 1.5km < distance to Airport Rail Link ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_MR	Distance to main road (km)	Calculated using GIS
DIST_EXP	Distance to expressway ramp (km)	Calculated using GIS
Work and non-work accessibility		
DIST_CBD	Distance to CBD: Siam Square (km)	Calculated using GIS
DIST_SHOPPING	Distance to shopping center (km)	Calculated using GIS
Neighborhood amenity		
MED_INC	Median income (baht)	The Transportation Model of Bangkok Metropolitan Region (e-Bum)
POP_DENS	Population density (persons/sq.km)	
Land attribute		
%_RESI_LAND	Percentage of residential land use	Bangkok Metropolitan Administration (BMA)
%_CON_LAND	Percentage of commercial land use	
%_INDUS_LAND	Percentage of industrial land use	
%_EDUC_LAND	Percentage of educational institute land use	
%_VAC_LAND	Percentage of vacant land use	
A_ROAD	Road pavement area (sq.km)	
A_SIDEWALK	Sidewalk area (sq.km)	

Table 5 - 2 Variables Description and Data Sources for Non-Residential Land Price

Variables	Description	Data Source
Local transportation accessibility		
DIST_STA	Distance to nearest station (km)	Calculated using GIS
DIST_GSTA0.5	Dummy variable (set 1, if distance to BTS Skytrain ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_GSTA1.0	Dummy variable (set 1, if 0.5km < distance to BTS Skytrain ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_GSTA1.5	Dummy variable (set 1, if 1.0km < distance to BTS Skytrain ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_GSTA2.0	Dummy variable (set 1, if 1.5km < distance to BTS Skytrain ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_BSTA0.5	Dummy variable (set 1, if distance to MRT Blue Line ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_BSTA1.0	Dummy variable (set 1, if 0.5km < distance to MRT Blue Line ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_BSTA1.5	Dummy variable (set 1, if 1.0km < distance to MRT Blue Line ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_BSTA2.0	Dummy variable (set 1, if 1.5km < distance to MRT Blue Line ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_ASTA0.5	Dummy variable (set 1, if distance to Airport Rail Link ≤ 0.5km, otherwise 0)	Calculated using GIS
DIST_ASTA1.0	Dummy variable (set 1, if 0.5km < distance to Airport Rail Link ≤ 1.0km, otherwise 0)	Calculated using GIS
DIST_ASTA1.5	Dummy variable (set 1, if 1.0km < distance to Airport Rail Link ≤ 1.5km, otherwise 0)	Calculated using GIS
DIST_ASTA2.0	Dummy variable (set 1, if 1.5km < distance to Airport Rail Link ≤ 2.0km, otherwise 0)	Calculated using GIS
DIST_MR	Distance to main road (km)	Calculated using GIS
DIST_EXP	Distance to expressway ramp (km)	Calculated using GIS
Work and non-work accessibility		
DIST_CBD	Distance to CBD: Siam Square (km)	Calculated using GIS
DIST_SHP	Distance to shopping center (km)	Calculated using GIS
Neighborhood amenity		
MED_INC	Median income (baht)	The Transportation Model of Bangkok Metropolitan Region (e-BUM)
POP_DENS	Population density (persons/sq.km)	
Land attribute		
%_RESI_LAND	Percentage of residential land use	Bangkok Metropolitan Administration (BMA)
%_CON_LAND	Percentage of commercial land use	
%_INDUS_LAND	Percentage of industrial land use	
%_EDUC_LAND	Percentage of educational institute land use	
%_VAC_LAND	Percentage of vacant land use	
A_ROAD	Road pavement area (sq.km)	
A_SIDEWALK	Sidewalk area (sq.km)	

Local transportation accessibility variable refers to the proximity to urban rail transit station, main road and expressway access which is similar to the variables used in land use change model (Chapter 4). Again, the straight line distance will be calculated using GIS. The expectation of these measures, that is, the land parcels being located near the urban rail transit station, main road and expressway access are worth than those being located farther away.

Next, work and non-work accessibility variable refers to the proximity to the central business district (CBD) and shopping center the same as land use change model (Chapter 4). This proxy is the straight line distance which calculated using GIS. The estimated coefficients of the measures should be negative, meaning that, land price increases as distance to the CBD and shopping center decreases.

Neighborhood amenity variable refers to median income (baht per month) and population density (persons per square kilometer). Median income has always proved to be important factor in residential location choice in order to capture the segregation phenomenon, i.e., people of similar income levels tend to cluster together when it comes to residential location. If this true, housing built in high income neighborhood can demand high price or rent and such sites will be able to offer high bid for residential use as explained in Chapter 4. Next, the expectation of population density, that is, I assume the areas with high population density because various housing and local service is more available than other areas which influence the land price uplift.

Finally, land attribute refers to the percentage of each type of land use and area of road pavement and sidewalk which obtained the statistic information from the Bangkok Metropolitan administration (BMA). The types of land use consist of residential land use, commercial land use, industrial land use, educational institute land use and vacant land use. The expectation is various depending on the types of land use of each parcel. For example, residential land parcels are less likely to develop near or high percentage of industrial land due to the safety. Thus, residential land parcels being located in the high percentage of industrial land will worth less than those being located in the lower percentage of industrial land area. On the other hand, residential land parcels tend to higher value in the areas with high percentage of commercial land use than those farther away.

5.5 Descriptive Statistics in Land Price and its Attributes

Among various types of required data, land value data used to carry out this chapter was obtained from the assessed land value reports, which were published by The Treasury Department, Thailand. The period time of land value is during the year 2008 and 2011.Geographic Information System (GIS) is used to plot the location of each land parcel. For the purposes of this study, data observations for residential and non-residential land parcels were selected. The total sample included 1,368 effective samples: 925 residential land parcels which mainly consist of single-detached housing and 443 non-residential land parcels which mainly consist of office building, retail shops and warehouses. The 1,368 land parcels investigated was illustrated in Figure 5 - 4. Additionally, blue dots indicate the residential land parcel used data; on the other hand, pink dots mean the non-residential land parcel used data.

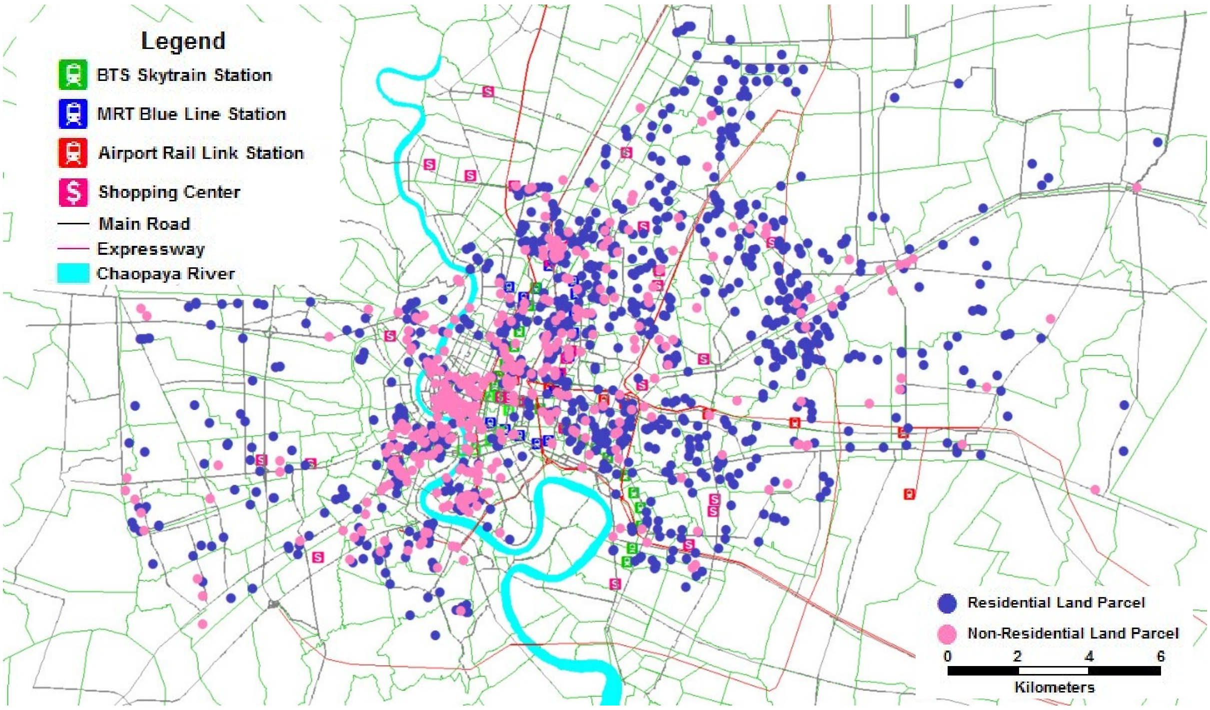

Figure 5 - 4 Locations of Observed Data

5.5.1 Descriptive Statistics: Residential Land Parcel

In Table 5 - 3, for the case of residential land parcels, a total of 925 observations were available. Let notice in the table, the average land price of residential parcels is approximately 34,000 baht per square meter or US$ 1,140 per square meter [3] but the minimum and maximum price is 1,300 baht per square meter (US$ 45 per square meter) and 305,000 baht per square meter (US$ 10,215 per square meter), respectively. Additionally, Figure 5 - 5 shows the distribution of land price by the color of the dot symbols, which are the location of the investigated residential parcel. In the figure, the land price in the inner city of Bangkok (such as the orange and red) is remarkably higher than the outer area (such as the light-red). Next, the average distance to the nearest BTS Skytrain station, MRT Blue Line station and Airport Rail Link station is 7.78, 8.01 and 7.71 kilometers, respectively. Additionally, higher shares of sampled residential parcels are near (i.e., within 10 kilometer of) a BTS Skytrain station (66.05 percent), MRT Blue Line station (64.11 percent) and Airport Rail Link station (72.97 percent). Figure 5 - 6 illustrates the distribution of distance the nearest station. It found that investigated parcel in the inner city is more ease of access to the nearest station than other area, in the other word; inner areas are served by the existing rail transit network. On average, the distance to the CBD is 12.25 kilometers while the distance to shopping mall is on average 4 kilometers. Median income in each district, on average, is around 30,000 baht per month or US$ 1,000 per month. Furthermore, the statistics show that household density is lower than employment density in areas near the sampled residential land parcels. Finally, the percentage of residential land use is the highest share (36.44 percent) than other uses, followed by the percentage of vacant (approximately 20.46 percent) and commercial (approximately 7 percent) land use. The road pavement and sidewalk area is 0.94 and 0.39 square kilometer, respectively.

[3] Exchange rate is 1 THB = 0.0335 USD (26 February 2013)

Table 5 - 3 Descriptive Statistics for Residential Land Parcels

Variables	N	Mean	Min	Max
Dependent Variable				
Land price (10,000 baht/sq.m)	925	3.38	0.13	30.50
Independent Variables				
Local transportation accessibility				
Distance to nearest station (km)	925	5.36	0.08	22.08
- proportion within 10 km of the station	775	3.69	0.08	9.99
- proportion more than 10 km of the station	150	14.04	10.04	22.08
Distance to nearest BTS Skytrain station (km)	925	7.78	0.08	35.99
- proportion within 10 km of the station	611	4.02	0.08	9.99
- proportion more than 10 km of the station	314	15.08	10.03	35.99
Distance to nearest MRT Blue Line station (km)	925	8.01	0.16	34.41
- proportion within 10 km of the station	593	4.26	0.16	9.99
- proportion more than 10 km of the station	332	14.71	10.01	34.41
Distance to nearest Airport Rail Link station (km)	925	7.71	0.11	22.66
- proportion within 10 km of the station	675	5.09	0.11	9.96
- proportion more than 10 km of the station	250	14.79	10.03	22.66
Distance to main road (km)	925	0.74	0.01	8.19
Distance to expressway ramp (km)	925	4.69	0.07	27.28
Work and non-work accessibility				
Distance to CBD: Siam Square (km)	925	12.25	0.85	40.49
Distance to shopping center (km)	925	3.62	0.13	23.45
Neighborhood amenity				
Median income (baht/month)	925	29,439.5	17,250	57,902
Household density (households/sq.km)	925	3,011	55	20,209
Employment density (positions/sq.km)	925	7,087	22	107,376
Land attribute				
Percentage of residential land use	925	36.44	6.50	61.38
Percentage of commercial land use	925	7.00	0.20	30.24
Percentage of industrial land use	925	1.59	0.10	7.51
Percentage of educational institute	925	2.23	0.20	12.92
Percentage of vacant land use	925	20.46	0.18	45.75
Road pavement area (sq.km)	925	0.94	0.25	2.53
Sidewalk area (sq.km)	925	0.39	0.06	3.07

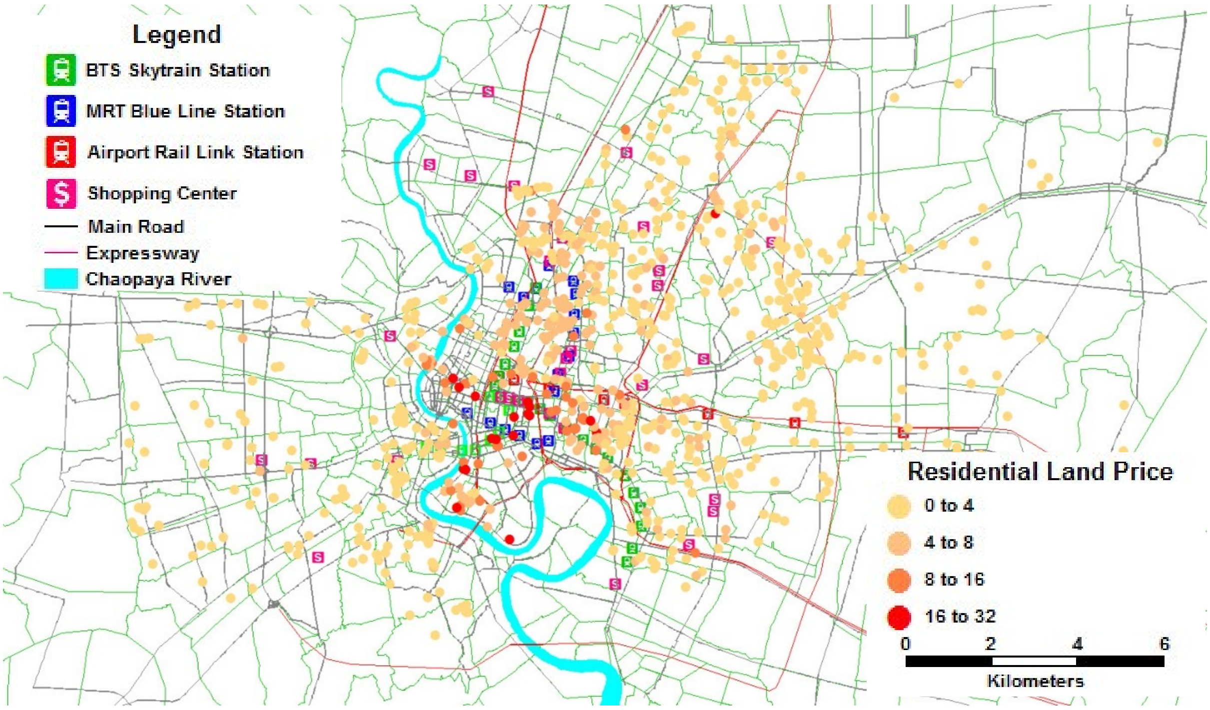

Figure 5 - 5 Residential Land Price (x10,000 baht/sq.m)

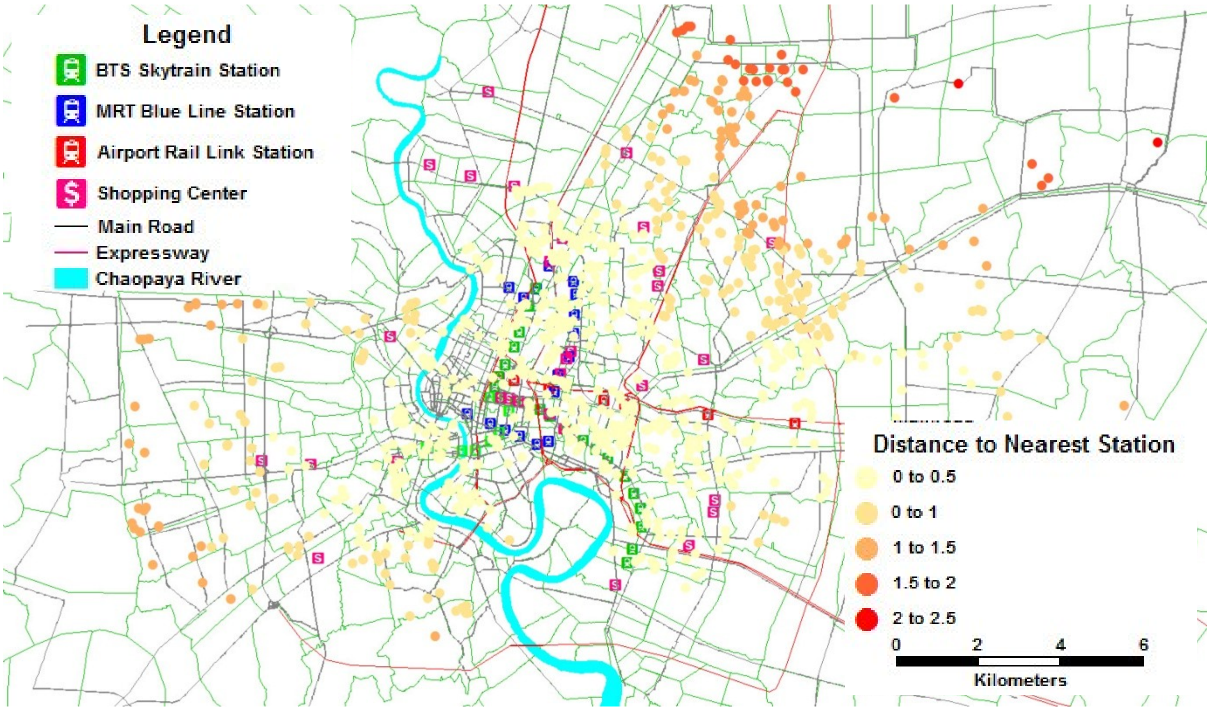

Figure 5 - 6 Distance to Nearest Station of Residential Land Parcels (x10 kilometers)

5.5.2 Descriptive Statistics: Non-Residential Land Parcel

In Table 5 - 4, for the case of non-residential land parcels, a total of 443 observations were available. The average land price of non-residential parcels is approximately 102,000 baht per square meter (US$3,415 per square meter) but the minimum and maximum price is 3,000 baht per square meter (US$ 100 per square meter) and 500,000 baht per square meter (US$ 16,750 per square meter), respectively. Not surprisingly, the average land price of non-residential parcel is more expensive than the average land price of residential parcel. In addition, Figure 5 - 7 shows the spatial distribution of land price by the color of the dot symbols, which are the location of the investigated non-residential parcel. The non-residential price distribution shows the same trend of the distribution of residential price, i.e., the parcels being located in the inner city (such as the orange and red) is more valuable than those located in the outer city (such as the light-red). Next, the average distance to the nearest BTS Skytrain station, MRT Blue Line station and Airport Rail Link station is 4.11, 4.61 and 5.58 kilometers, respectively. This result indicates that the samples of non-residential land parcels in this study tend to be closer the urban rail transit station than the samples of residential parcels due to the fact that existing urban rail transit network is located in the core of the city where many office building and shopping mall have been built. Additionally, higher shares of sampled residential parcels are near (i.e., within 10 kilometers of) a BTS Skytrain station (88.71 percent), MRT Blue Line station (67.13 percent) and Airport Rail Link station (87.58 percent). Conversely, around 10 percent of investigated non-residential land parcels appear in area far from stations among three urban rail transit more than 10 kilometers. Figure 5 - 8 provides the spatial distribution of distance the nearest station. It found that investigated parcel in the inner city is more ease of access to the nearest station than other area, in the other word; inner areas are served by the existing rail transit network. On average, the distance to the CBD is 7.36 kilometers where there are located in areas closer to the CBD than residential land parcels. Non-residential land parcels are closer to expressway ramp so as to easy access to transportation networks Similarly, the distance to shopping mall, on average, 2.85 kilometers that is less than the average distance of investigated residential parcels. Median income in each district, on average, is around 33,034.6 baht per month or US$ 1,105 per month. Besides, the table also provides the spatial distribution of diverse activities in Bangkok Metropolitan Area. On average, non-residential parcels tend to be in the densest setting and predictably. Moreover, non-residential parcels are generally in the highest income neighborhoods, opposite of residential parcels. Finally, the percentage of residential land use is the highest share than other uses (35.42 percent). The road pavement and sidewalk area is 0.80 and 0.32 square kilometer, respectively.

Table 5 - 4 Descriptive Statistics for Non-Residential Land Parcels

Variables	N	Mean	Min	Max
Dependent Variable				
Land price (10,000 baht/sq.m)	443	10.24	0.30	50.00
Independent Variables				
<u>*Local transportation accessibility*</u>				
Distance to nearest station (km)	443	2.84	0.04	19.37
- proportion within 10 km of the station	422	2.05	0.04	9.94
- proportion more than 10 km of the station	21	12.39	10.07	19.37
Distance to nearest BTS Skytrain station (km)	443	4.11	0.06	33.66
- proportion within 10 km of the station	393	2.95	0.06	9.86
- proportion more than 10 km of the station	50	16.11	10.09	33.66
Distance to nearest MRT Blue Line station (km)	443	4.61	0.04	32.73
- proportion within 10 km of the station	386	2.95	0.04	9.77
- proportion more than 10 km of the station	57	15.85	10.00	32.73
Distance to nearest Airport Rail Link station (km)	443	5.58	0.07	22.43
- proportion within 10 km of the station	388	4.39	0.07	9.94
- proportion more than 10 km of the station	55	13.99	10.01	22.43
Distance to main road (km)	443	0.31	0.004	5.58
Distance to expressway ramp (km)	443	2.77	0.04	25.81
<u>*Work and non-work accessibility*</u>				
Distance to CBD: Siam Square (km)	443	7.36	0.83	38.51
Distance to shopping center (km)	443	2.85	0.09	21.87
<u>*Neighborhood amenity*</u>				
Median income (baht/month)	443	33,034.6	18,451	57,902
Household density (households/sq.km)	443	5,352.5	55	34,400
Employment density (positions/sq.km)	443	20,469	22	250,532
<u>*Land attribute*</u>				
Percentage of residential land use	443	35.42	6.50	61.38
Percentage of commercial land use	443	11.86	0.20	38.28
Percentage of industrial land use	443	1.47	0.07	7.51
Percentage of educational institute	443	3.04	0.20	12.92
Percentage of vacant land use	443	12.64	0.18	45.75
Road pavement area (sq.km)	443	0.82	0.25	2.53
Sidewalk area (sq.km)	443	0.30	0.06	3.07

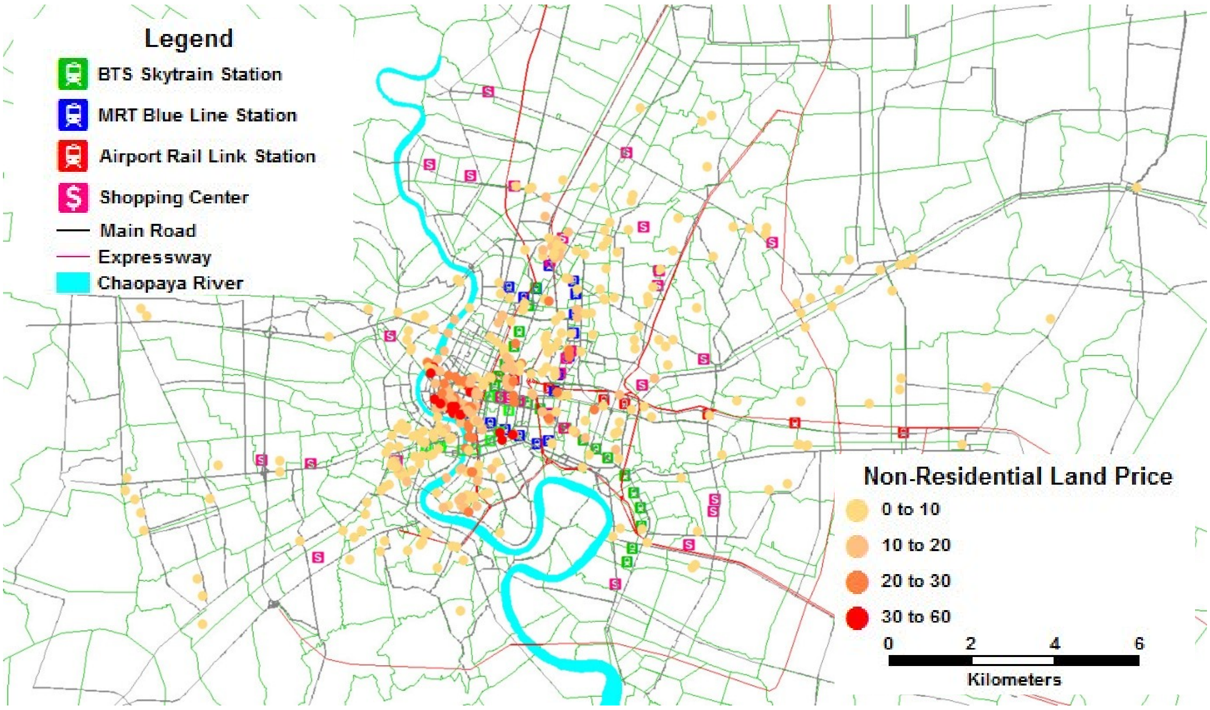

Figure 5 - 7 Non-Residential Land Price (x10,000 baht/sq.m)

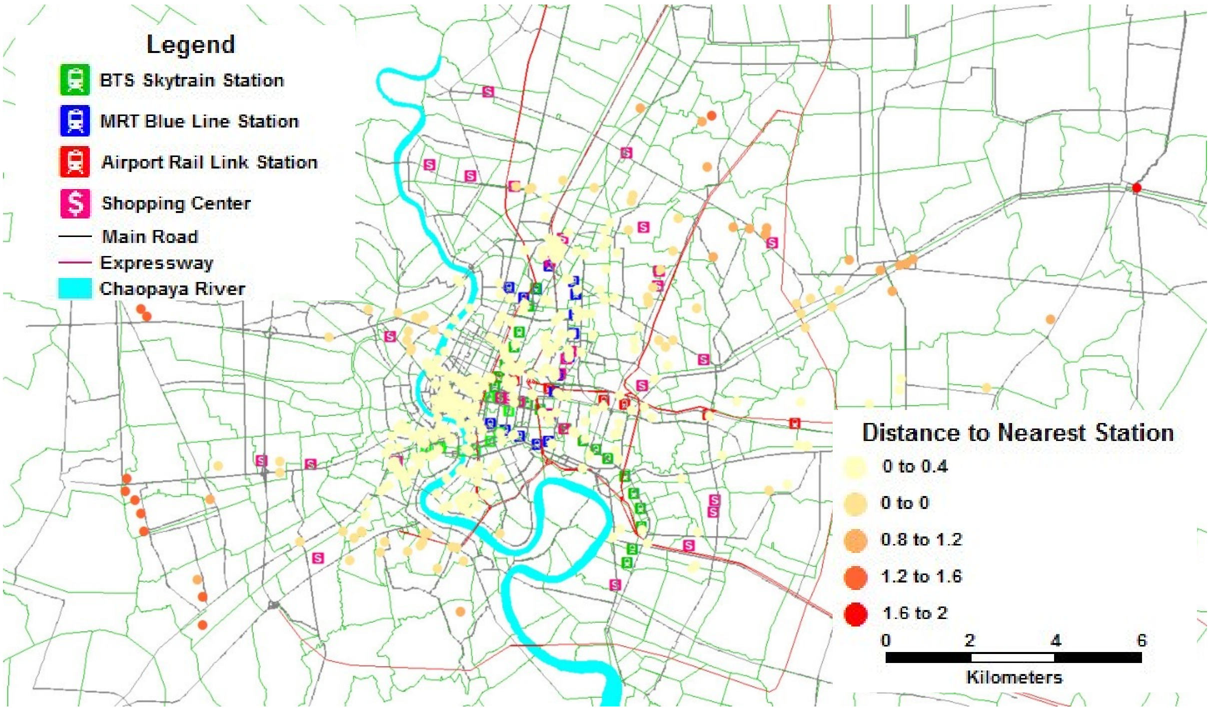

Figure 5 - 8 Distance to Nearest Station of Non-Residential Land Parcels (x10 kilometers)

5.6 Changes in Land Price along the Urban Rail Transit Corridor

In order to investigate the impact of urban rail transit on land price, the case study is, first, an area along a corridor of BTS Skytrain, which is the first urban rail transit in Bangkok, having been in service for over 10 years. Next, the area along the corridor of MRT Blue Line is known as the second urban rail transit. Finally, the area nearby the corridor of Airport Rail Link which direct links between

Suvarnbhumi Airport and the center of Bangkok, started its service 4 years ago. These three urban rail transit lines are now operating.

5.6.1 Changes in Land Price: BTS Skytrain

As explained, the BTS Skytrain is the first of urban rail transit in Bangkok Metropolitan Region and composes of two sub-lines namely Silom Line and Sukhumvit Line. Figure 5 - 9 illustrates land price near the BTS Skytrain stations at four periods: during 1996-1999 (blue bar), 2000-2003 (red bar), 2004-2007 (green bar) and 2008-2011 (purple bar).

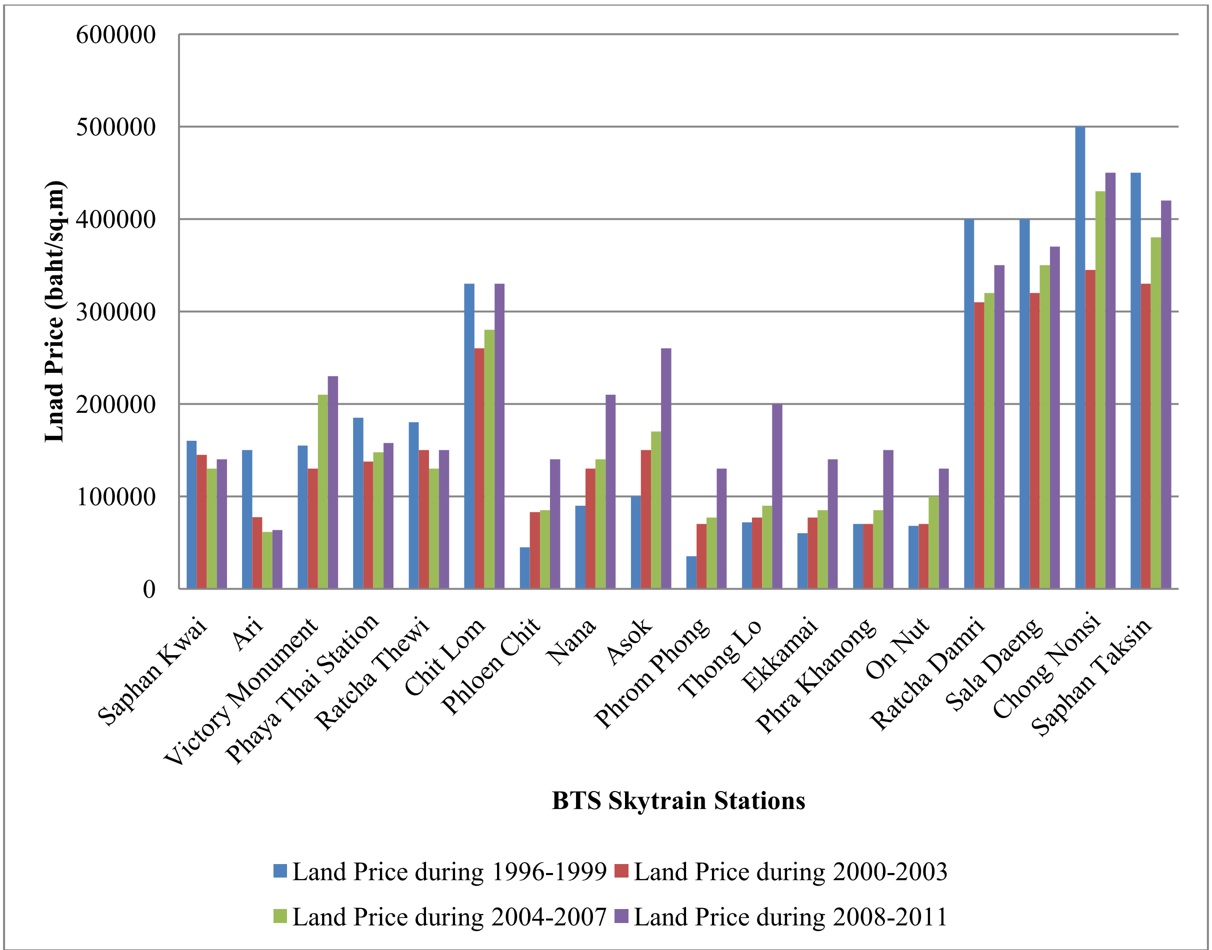

Figure 5 - 9 Land Price near the BTS Skytrain Stations

Figure 5 - 9 shows that the official land value near Chit Lom station, Ratcha Damri station, Sala Daeng station, Chong Nonsi station, and Saphan Taksin station is remarkably more valuable than other stations. These areas even before BTS Skytrain construction are known as the concentration of employment sectors: commercial and financial sectors. This is the reason that these areas can bid the high land price. Conversely, surrounding areas of other stations such as Saphan Kwai, Phrom Phong, and Thong Lo station are used as mixed-land with higher shares of residential use.

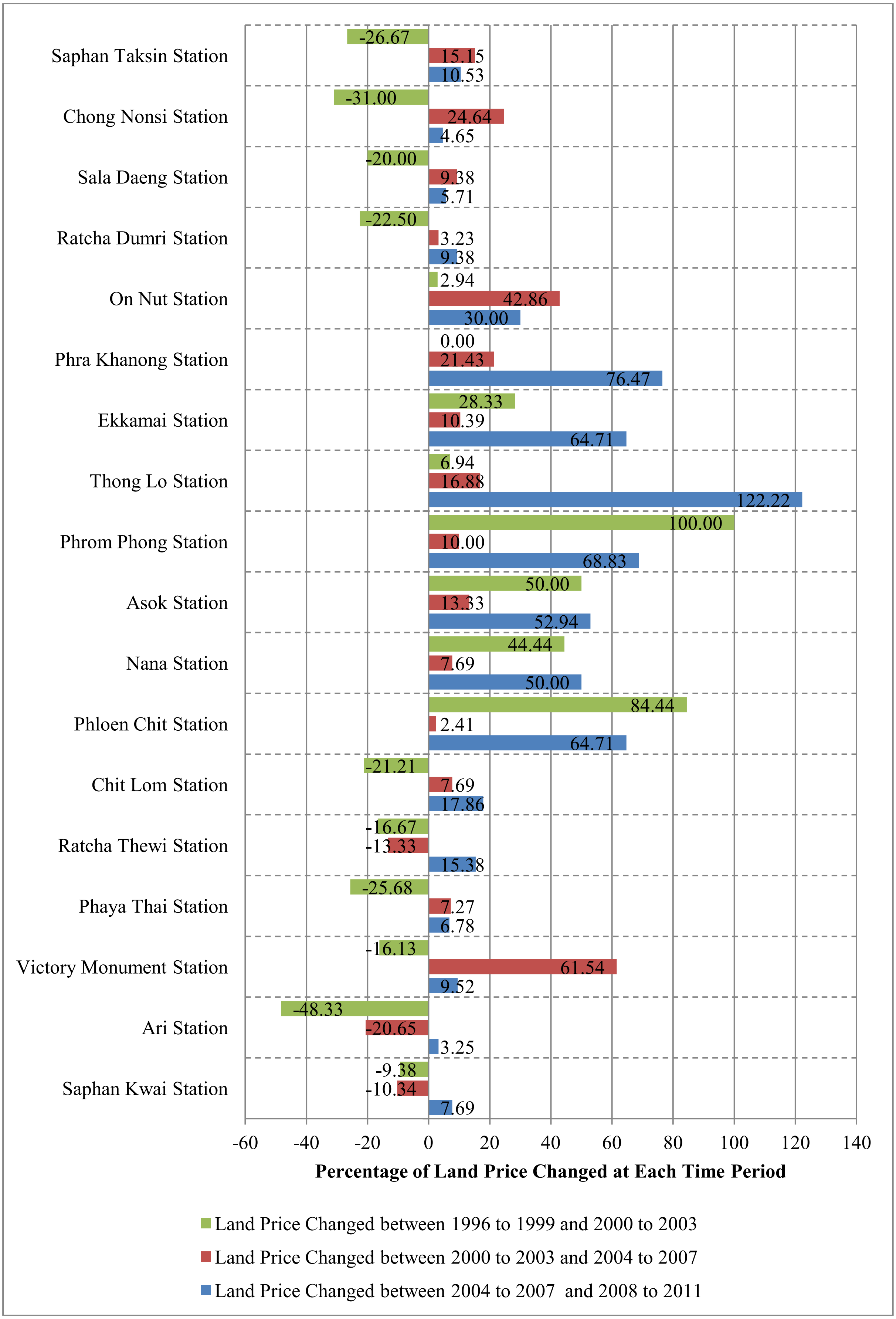

Figure 5 - 10 Land Price Appreciation along BTS Skytrain

Next, the change in land price is observed by comparing the official land value appraisal at BTS Skytrain stations. Figure 5 - 10 shows the changes in an official land value from 1996 to 2008 at several reference points, i.e., the stations of BTS Skytrain. The color bars at representative locations compare the appraised land value at different years. The green bar indicates the changes between the year 1996 and 2000, that is, before BTS started its service. The red bar refers to the changes between the year 2000 and 2004, that is, after the first four years of full operation. The third one is the change between 2004 and 2008 after opened its service eight years ago, indicated by blue bar. This situation is varying depending on time schedule of each line.

Let notice the figure, the first period of comparison, green bar (during the construction), is obvious that the value in the year 2000 has significantly dropped due to the economic recession in 1998 in most stations such as Saphan Taksin station, Chong Nonsi station, Sala Daeng station, Chit Lom station which are located in the business area as explained. On the other hand, stations surrounding by mixed-use with higher shares of residential uses such as On Nut station, Phra Khanon station, Ekkamai station, Phrom Phong station, Asok station, Nana station has gained rapid increment during constructed rail transit infrastructure. In addition, the highest change was found at Phrom Phong station (around 100 percent). This is followed by Phloen Chit station (89 percent), Asok station (50 percent) and Nana station (44 percent).

After the first four years operating (red bar), land price is again obvious that land along those stations (e.g. On Nut station, Phra Khanon station) located in residential area is still slightly increasing. Notably, land near On Nut station increased with a higher percentage compared with land near other stations. This is followed by land price in area of Phra Kanong station. However, the remarkably change was found at the adjacent area of Victory Monument station, another hub for shopping scene and land transport.

Recently, the eight years later (blue bar), the official price located in residential area is significantly increasing especially near Thong Lo station (122 percent), Phra khanong station (76 percent), Phrom Phong station (69 percent) and Ekkamai station (65 percent). Not surprising, there are rapid development as can be seen by the continuous rise of new residential (e.g. luxury condominium and apartment) in these areas.

This is claimed to be caused by the BTS Skytrain development bring the good opportunities to these areas. For example, in past, certainly before the BTS Skytrain construction, The Monument and Asok intersection was one of the most congested intersections in Bangkok; its surrounding area had unavoidably became less accessible and valued due to the traffic congestion. On the other hand, On Nut, Phra Kanong, Ekkamai, Thong Lo and Phrom Phong area is known as the outer residential area in the past where travel by public transport is not convenient and inadequacy. But after BTS Skytrain exists and provides high level of public transport service, among areas has become to be attractive for the developers with higher demand.

5.6.2 Changes in Land Price: MRT Blue Line

The MRT Blue Line is the second of urban rail transit in Bangkok Metropolitan Region. Figure 5 - 11 illustrates land price near the MRT Blue Line stations at four periods: during 1996-1999 (blue bar), 2000-2003 (red bar), 2004-2007 (green bar) and 2008-2011 (purple bar).

Figure 5 - 11 shows that the official land value near Phechaburi station, Sukhumvit station, Lumphini station, Silom station and Sam Yan station is remarkably more valuable than other stations. These areas even before MRT Blue Line construction are known as the high density of commercial area. This is the reason that these areas can bid the high land price. Furthermore, Sukhumvit station and Silom station is transfer station between BTS Skytrain and MRT Blue Line. Surrounding areas of Kamphaeng Phet station and Phaholyothin station are another hub of trader-commercial center.

Conversely, surrounding areas of other stations such as Ratchadapisek station, Suthisan station, Huai Khwang station, and Thailand Cultural Centre station are higher used for residential.

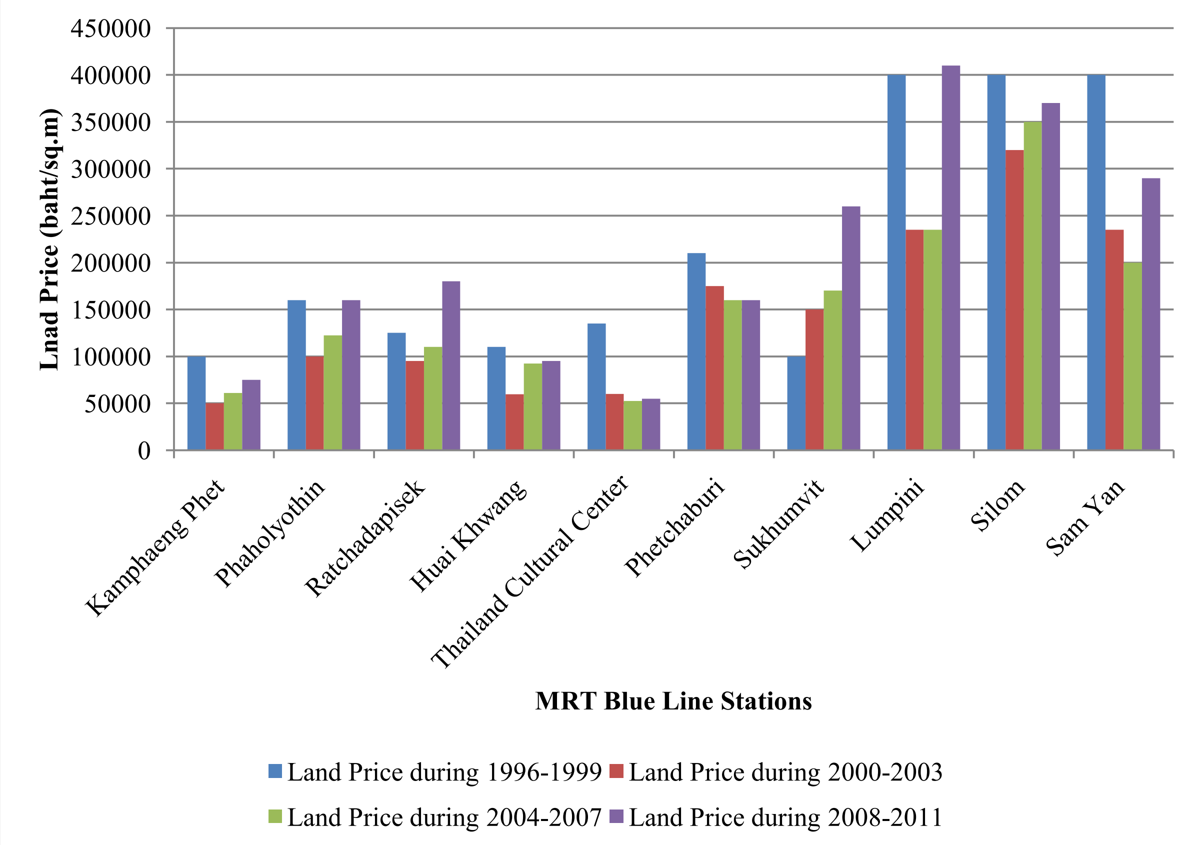

Figure 5 - 11 Land Price near the MRT Blue Line Stations

Next, the change in land price is observed by comparing the official land value appraisal at MRT Blue Line stations. It has 18 operational stations along 27 kilometers of underground track. Surrounding area of 11 MRT Blue Line stations were tracked the changes in land price at the same period spans as observed the changes in land price of BTS Skytrain. The result is illustrated in Figure 5 - 12. This figure shows the changes in an official land value from 1996 to 2008 at several reference points. The color bars at representative locations compare the appraised land value at different years. The green bar indicates the changes between the year 1996 and 2000, that is, closely before MRT Blue Line started construction. The red bar refers to the changes between the year 2000 and 2004, that is, during constructed urban rail transit infrastructure. The third one is the change between 2004 and 2008 after the first four year of operation, indicated by blue bar. This situation is different from the period of BTS Skytrain.

Let notice the figure, the first period of comparison, green bar, is obvious that the value in the year 2000 has remarkably dropped as the results the economic crisis in 1998 as explained in all stations except Sukhumvit station which is the transfer station between BTS Skytrain and MRT Blue Line.

During MRT Blue Line construction (red bar), land price at most stations such as Silom station, Sukhumvit station, Huai Khwang station and Phaholpothin station was becoming more valuable. Notably, land near Huai Khwang station increased with a higher percentage (55 percent) compared with land near other stations. This is followed by Phahonyothin station (23 percent), Kamphaeng Phet station (22 percent) and Ratchadapisek station (16 percent).

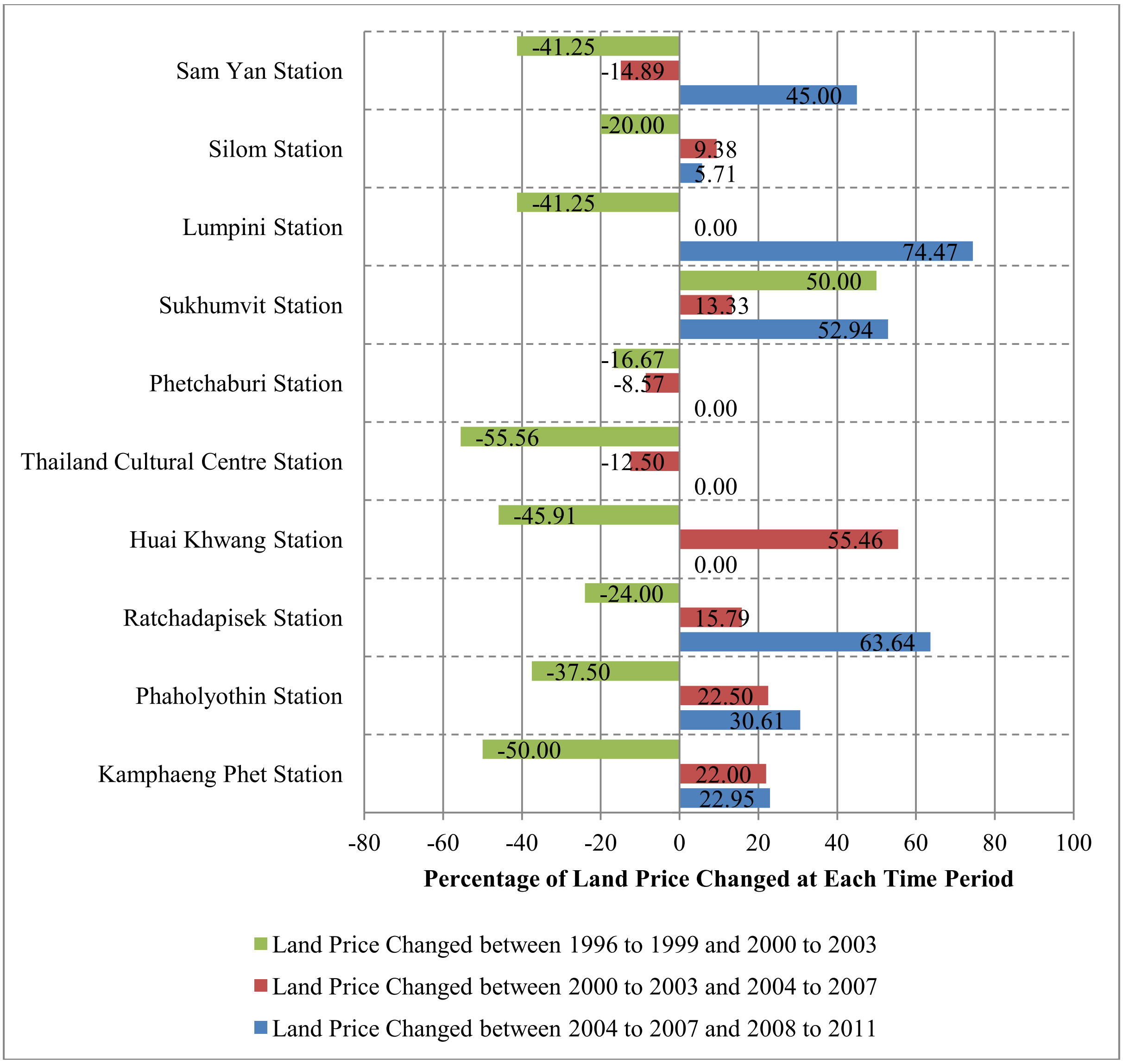

Figure 5 - 12 Land Price Appreciation along MRT Blue Line

After the first four years operating (blue bar), the official price in commercial area significantly increased at Lumphini station (74 percent) and followed by 64 percent at Ratchadapisek station where there are rapid development as can be seen by the continuous rise of new residential (e.g. luxury condominium and apartment) in this area similar to the adjacent area of Thonglor station, Ekkamai station and etc. Furthermore, the remarkably change was found at the adjacent of transfer stations, namely, Sukhumvit station (50 percent). Besides, Sam Yan station, the large campus of Chulalongkorn University lies nearby, is obvious that the change of value increased. Additionally, Chulalongkorn University, which owns the areas near Sam Yan intersection, began work on development plan being the complex center of commercial office tower and residential tower so-called as Chamchuri square.

This is also claimed to be caused by the MRT Blue Line development bring the good opportunities to these areas. For example, in past, certainly before the MRT Blue Line construction, The Rachadapisek, Huai Khwang and Phaholyothin intersection was one of the most congested intersections in Bangkok; its surrounding area had unavoidably became less accessible and valued due to the traffic congestion. But after MRT Blue Line exists and provides high level of public transport service, among areas has become to be attractive for the developers with higher demand.

5.6.3 Changes in Land Price: Airport Rail Link

Airport Rail Link is the third urban rail transit in Bangkok Metropolitan Region. Services consists of two Express Lines, a 15-minute non-stop service between Suvarnabhumi Airport and Makkasan station, an 18-minute non-stop service between Suvarnabhumi Airport and Phaya Thai station and the City Line, stop every stations. Figure 5 - 13 illustrates land price near the Airport Rail Link stations at four periods: during 1996-1999 (blue bar), 2000-2003 (red bar), 2004-2007 (green bar) and 2008-2011 (purple bar).

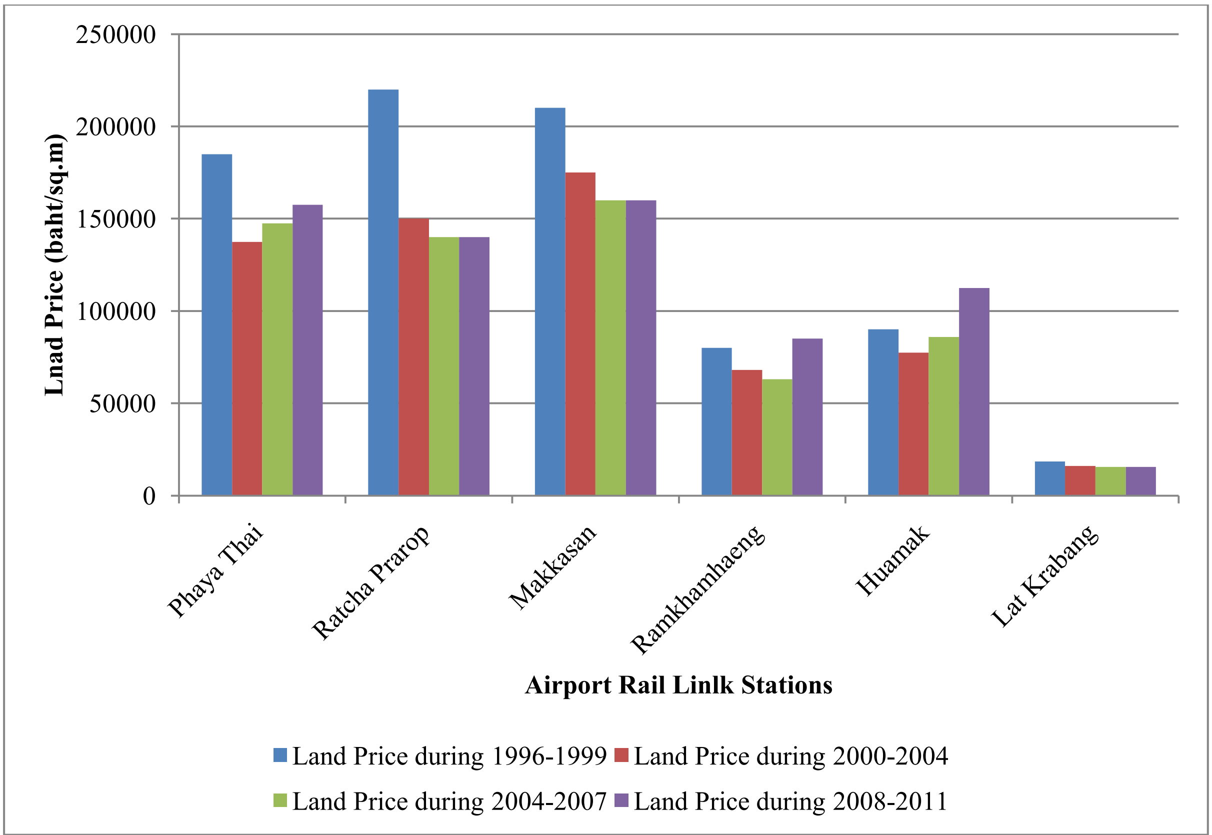

Figure 5 - 13 Land Price near the Airport Rail Link Stations

Figure 5 - 13 shows that the official land value near Phaya Thai station, Ratcha Prarop station and Makkasan station is remarkably more valuable than other stations. These areas locate in central Bangkok. This is the reason that these areas can bid the high land price. Phaya Thai station is transfer station between BTS Skytrain and Airport Rail Link. Furthermore, the Airport Rail Link can connect to the MRT Blue Line by via Makkasan station to Petchaburi station. Conversely, surrounding areas of other stations, i.e., Ramkhamhaeng station, Hua Mak station, and Lak Krabang station, are higher share of residential areas.

Surrounding area of six Airport Rail Link stations were tracked the changes in land price during the year 1996 and 2008. The result is illustrated in Figure 5 - 14. The color bars at representative locations compare the appraised land value at different years. The green bar indicates the changes between the year 1996 and 2000, that is, before Airport Rail Link announcement and sign contract. The red bar refers to the changes between the year 2000 and 2004, that is, before Airport Rail Link started construction. The third one is the change between 2004 and 2008, that is, during constructed urban rail transit infrastructure, indicated by blue bar.

Nearly before Airport Rail Link construction, the official price at all station was steady, give or takes a few. Notably, only Hua Mak station has remarkably increased at 11 percent and 31 percent between the year 2000 and 2004 and the year 2004 and 2008, respectively. Next, the figure is also obvious that the value at Ramkhamhaeng station in the year 2004 and 2008 has the highest percentage changed around 35 percent. However, it is cannot found the changes between the transfer station, namely, Phaya Thai station.

For this line, it cannot be said that in influence of Airport Rail Link is having on the land price or not due to the fact that it is nearly three years' full operation. Furthermore, the purpose of this line is to serve between the central Bangkok and Suvarnabhum Airport with the express transit. This may be the reason that it cannot seen the effects of its availability in most stations except Hua Mak station which bypass from express line to the city line via a passing loop.

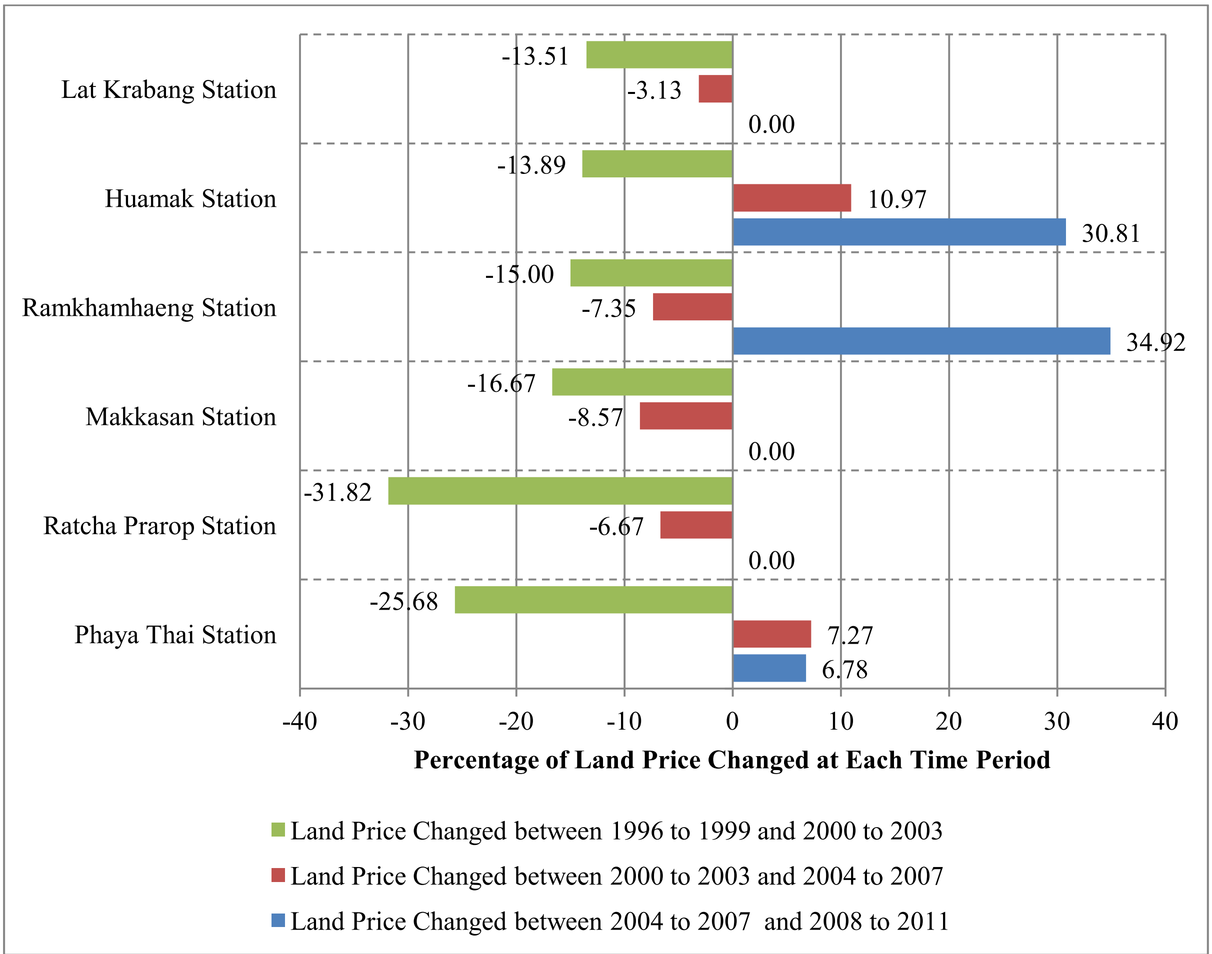

Figure 5 - 14 Land Price Appreciation along Airport Rail Link

5.7 Land Price Model Specification

A global regression framework is then applied to determine the value of land based on its attributes. Furthermore, the variations of the influences on the land price are revealed by considering different groups of land cover features and incorporating spatial effects, namely spatial dependence and heterogeneity.

The global regression assumes that relationship is constant over space. However, the relationship often might vary across space because the attributes are not the same in different locations. Therefore, it is natural to suspect the spatial effects association between land price and its attributes in particular proximity factors. Spatial dependence refers to a situation that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). The statistical test for spatial dependence was defined by Anselin (1981), the so-called spatial autoregressive model (SAR). While spatial heterogeneity refer to a situation that the measurement of a relationship depends in part on where the measurement is taken (Fotheringham *et al.*, 2002). The statistical test for spatial heterogeneity is based on the geographically weighted regression model (GWR). The urban rail transit investment impacts on land use and land development and increases in property value are well recognized in developed countries but less investigated in developing countries especially accommodating the spatial effects in the models. Therefore, the challenge of this section is using a spatial econometric method to appreciate the facets of this land price data.

5.7.1 Global Regression Model

Regression analysis is used to model the relationship between one (or more) dependent or response variables and a number of independent or predictor variables. The general regression model can be specified as follows:

$$y = \boldsymbol{X}\boldsymbol{\beta} + \varepsilon \tag{5.1}$$

$$E[\boldsymbol{\varepsilon}] = \mathbf{0} \tag{5.2}$$

$$\boldsymbol{\Omega} = E[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'] = \sigma^2\mathbf{C} \tag{5.3}$$

where $\boldsymbol{y}$ is a vector (n×1) of observations corresponding to a dependent variable, $\mathbf{X}$ is a matrix (n×k) of observations of k independent variables, $\boldsymbol{\beta}$ is a vector (k×1) of regression parameters, $\boldsymbol{\varepsilon}$ is a vector (n×1) of errors, and $\mathbf{C}$ is a positive definite covariance matrix. The errors are often assumed to be normally distributed with an expected value of 0 and a variance-covariance matrix $\boldsymbol{\Omega}$ of size n×n. Hence, classical ordinary least square (OLS) is obtained by defining $\boldsymbol{\Omega} = \sigma^2\mathbf{I}$ and the solution for the coefficients of is obtained:

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{y} \tag{5.4}$$

5.7.2 Local Regression Model

Some of previous studies focus on local variation of the impact by incorporating the nonstationarity; a situation when parameter estimates vary with different spatial entity used. A study in Tyne and Wear Region, UK has employed the Geographically Weighted Regression (GWR) approach and revealed that nonstationarity existing in the relationship between transport accessibility and land value (Du and Mulley, 2006). It is showed that transport accessibility may have a positive effect on land value in some areas but in others a negative or no effect, suggesting that a uniform land value capture would be inappropriate. Paez and Suzuki (2001) examined the impact of transportation on land use change by looking at local effect by using GWR.

GWR is the term introduced by Fotheringham *et al.* (2002) to describe a family of regression models in which the coefficients, $\boldsymbol{\beta}$, are allowed to vary spatially. The regression model in equation (5.1) may be rewritten for each local model at observation location o as follows.

$$y_o = \boldsymbol{X}_o\boldsymbol{\beta}_o + \varepsilon_o \tag{5.5}$$

where the sub-index o indicates a observation point where the model is estimated. The coefficients $\boldsymbol{\beta}_\mathbf{o}$ are determined by examining the set of points within a well-defined neighborhood of each of the sample points. This neighborhood is essentially a circle, radius r, around each data point. However, if r is treated as a fixed value in which all points are regarded as of equal importance, it could include every point (for r large) or alternatively no other points (for r very small). Instead of using a fixed value for r it is replaced by a distance-decay function, *f(d)*. Various functional forms of *f(d)* are available. A simple function may be defined such as $f(d) = \quad - \quad$, where d is the distance between the focus point o and other data points, and h is a parameter (is also called bandwidth). A small bandwidth results in very rapid distance decay, whereas a larger value will result in a smoother weighting scheme. This parameter may be defined manually or alternatively by some forms of adaptive method such as cross-validation minimization or minimization of the Akaike Information Criterion (AIC). Following the framework of equation, the variance-covariance matrix for the GWR model may be defined as:

$$\boldsymbol{\Omega}_o = E[\boldsymbol{\varepsilon}_o \boldsymbol{\varepsilon}_o] = \sigma_o^2 \mathbf{C}_o \tag{5.6}$$

The diagonal elements of matrix $\mathbf{C}_o$ are given by

$$g_{oi}(\gamma_o, d_{oi}) = \exp(\gamma_o d_{oi}^2) \tag{5.7}$$

where the off-diagonal elements are all equal to 0.

The variance is defined as a function of two parameters, namely σ_o^2 and γ_o, and d_{oi} is the distance between focal point o and observation i =1,…, n. The advantage of using an exponential function such as equation (5.7) is that the i^{th} diagonal element of the covariance matrix $\omega_{oi} > 0$ as long as $\sigma_o^2 > 0$, thus ensuring positive definiteness. Assuming normally distributed errors with a variance-covariance matrix as in equation (5.6) and (5.7), the local parameter estimates can be obtained:

$$\hat{\boldsymbol{\beta}}_o = (\mathbf{X}'\mathbf{C}_o^{-1}\mathbf{X})^{-1}\mathbf{X}'\mathbf{C}_o^{-1}\boldsymbol{y} \tag{5.8}$$

$$\hat{\sigma}_o^2 = \frac{1}{n}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)'\mathbf{C}_o^{-1}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o) \tag{5.9}$$

These are conditional upon a structure of matrix $\mathbf{C}_o$. These estimators, when substituted and introduced into the corresponding log-likelihood function, result in a concentrated function that depends on a single parameter, namely γ_o:

$$-\frac{n}{2}\ln\left[\frac{1}{n}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)'\mathbf{C}_o^{-1}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)\right] - \frac{1}{2}\sum_{i=1}^{n}\gamma_o d_{oi}^2 \tag{5.10}$$

The above function can be numerically maximized with respect to γ_o to obtain a parameter that can be substituted in equation (5.10) to obtain the maximum likelihood estimates for $\hat{\boldsymbol{\beta}}_o$.

5.8 Influencing Factors in Determining Land Price

This section presents the results for the two types of land uses; residential and non-residential land parcels, along with the spatial variations of the parameters in maps that measured land value premiums or discounts.

5.8.1 Land Price Model: Residential Land Parcel

Table 5 - 5 presents the residential land price model which was calibrated by the ordinary least squares (OLS) and geographically weight regression (GWR) method, respectively. The goodness-of-fit is evaluated by the coefficient of determination (R^2), Akaike's Information Criterion (AIC), and residual sum of squares (RSS) which are measured how well the models are. In addition, the coefficient of determination (R^2) is the accuracy of the predictor of independent variables on dependent variable value (land price), i.e., the higher the coefficient of determination, the better the

variance that land price is explained by its attributes. Akaike's Information Criterion (AIC) is evaluated based on the value of likelihood function and weights in the trade-off of how much information is obtained and the number of variables used while residual sum of squares (RSS) is a measure of the discrepancy between the data and an estimated model.

As mentioned, the OLS model is estimated where the resulting coefficients are global meaning that the coefficients are constant over the study area while the GWR model gives local parameter estimates for each observation points, i.e., a total of 925 sets of estimates are obtained. However, Table 5 - 5 shows only minimum, maximum, and median values. The estimation framework is the same trend as global regression (OLS model). The independent variables used to estimate the price model were divided into four categories: local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute as explained in Chapter 4. After extensive experimentations with different specifications, all models were chosen based on the theoretical and statistical significance of the estimated parameters.

Next, from the table, the equation of land price model for residential land value is shown as follows;

OLS Model: 0.6772xDIST_STA – 0.3147xDIST_MR – 0.3192xDIST_EXP – 0.7063xDIST_CBD – 0.0329xDIST_SHOPPING + 0.2470xMED_INC + 0.1510xEMP_DENS – 0.7164x%_RESI_LAND + 4.3789x%COM_LAND – 4.8908x%INDUS_LAND + 4.3273x%EDUC_LAND + 0.2761x%VAC_LAND – 1.2850xA_ROAD + 0.7774xA_SIDEWALK

GWR Model: *– 0.5292xDIST_STA – 0.9194xDIST_MR + 0.6216xDIST_EXP – 1.0082xDIST_CBD – 0.8821xDIST_SHOPPING + 0.1001xMED_INC – 0.1237xEMP_DENS – 0.0114x%_RESI_LAND + 2.1985x%COM_LAND – 2.1873x%INDUS_LAND + 5.6085x%%EDUC_LAND + 0.1552%_VAC_LAND – 0.8567xA_ROAD + 0.5760xA_SIDEWALK*

Let notice Table 5 - 5, with those statistically significant coefficients suggests that the GWR model has much better predictive powers than the OLS model, explaining around 70 percent of the variation in assessed prices among 925 parcels, which mainly consisted of single-detached housing and multi-attached housing. AIC in the GWR model is also lower than the OLS mode. With the residual sum of squares for both the GWR and the OLS being compared, the lower GWR residuals suggest that there is a significant improvement in the model fit when the GWR is adopted. Based on a Monte Carlo test procedure, some independent variables were insignificant at the 5% level in the global parameter estimated but the GWR can examine the significance of the spatial variability of parameters, suggesting that these factors, e.g., distance to expressway access and distance to shopping center, were a factor in some areas but not in other areas. The results of the final specification are discussed as below.

Table 5 - 5 Residential Land Price Model: Global Regression Model (OLS) and Local Regression Model (GWR)

Variables	OLS				GWR				
	Parameter	t-Statistic	P-value		Min	Max	Mean	P-value	
Local transportation accessibility									
DIST_STA	0.6772	1.9552	0.0510	*	-13.8494	13.8457	-0.5292	0.0000	***
DIST_MR	-0.3147	-2.4764	0.0130	**	-4.0575	0.0634	-0.9194	0.0000	***
DIST_EXP	-0.3192	-0.7553	0.4500	n/s	-8.8438	13.5702	0.6216	0.0000	***
Work and non-work accessibility									
DIST_CBD	-0.7063	-1.8380	0.0660	*	-13.7954	6.5492	-1.0082	0.0000	***
DIST_SHOPPING	-0.0329	-0.0626	0.9500	n/s	-13.0362	11.2070	-0.8821	0.0000	***
Neighborhood amenity									
MED_INC	0.2470	1.5873	0.1130	n/s	-2.3573	1.4834	0.1001	0.0100	**
EMP_DENS	0.1510	1.8045	0.0710	*	-0.7587	0.6667	-0.1237	0.8800	n/s
Land attribute									
%_RESI_LAND	-0.7164	-5.7327	0.0000	***	-2.5027	4.4296	-0.0114	0.0000	***
%_COM_LAND	4.3789	13.6955	0.0000	***	-3.0670	8.1169	2.1985	0.0000	***
%_INDUS_LAND	-4.8908	-7.6823	0.0000	***	-27.9951	11.9752	-2.1873	0.0000	***
%_EDUC_LAND	4.3273	7.4869	0.0000	***	-12.8912	18.1230	5.6085	0.0000	***
%_VAC_LAND	0.2761	2.0191	0.0440	**	-2.4573	3.5395	0.1552	0.0000	***
A_ROAD	-1.2850	-5.4692	0.0000	***	-8.8638	5.3281	-0.8567	0.0000	***
A_SIDEWALK	0.7774	2.2135	0.0270	**	-14.3102	19.5382	0.5760	0.0000	***
R^2		0.5094					0.6808		
AIC		4,329.2508					4,093.4271		
RSS		5,636.0882					3,667.6317		

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

5.8.1.1 Global Regression Model: Residential Land Price

For the OLS model, some independent variables, the attributes of each land parcel, had expected signs. Among local transportation accessibility, straight line distance to main road (DIST_MR) and expressway entrance's access (DIST_EXP) have negative as expected, meaning that residential land parcel being located near main road and expressway access are more valuable than those being located far away from main road and expressway access. Obviously, this is reflected by the new development and re-development properties along road network. Such premium is probably due to good opportunities to road and expressway network. However, the parameter of distance to urban rail transit station shows the positive sign, meaning that although the distance to urban rail transit station is large, the price is still not decreasing. The reason that is perhaps the access to the urban rail transit is not based on non-motorized modes such as walking or cycling. Therefore, the distance to the station will not be the primary factor directly driving up land price.

Among work and non-work accessibility, two independent variables, distance to CBD (DIST_CBD) and shopping mall or shopping center (DIST_SHOP), were used to investigate. Both variables show the negative sign. These results mean that the residential land parcels with greater accessibility to central business district (CBD) is more expensive, in the other word, this proxy variable represents the closeness to the city center, i.e., farther residential parcels are again cheaper. Similarly, price also tends to be higher in the area near shopping mall or shopping center.

For neighborhood amenity, two independent variables, median income (MED_INC) and employment density (EMP_DENS) were used to estimate residential land price model. The result shows that residential land parcels gain a higher premium, as the median income of zone increases. Thus, it is more likely for luxury housing development to occur where median income is high. Next, higher employment density also tends to increase residential land value.

For land attribute, the percentage of residential area and road areas tends to reduce residential land value. However, sidewalk areas create benefit to the residential land price. A higher percentage of industrial area is more likely to lower the value. Obviously, residential development rarely occurs near the industry. On the other hand, a higher proportion of commercial area confers a premium on residential land value due to bid-rent completion. Likewise, land parcel being located in area with higher shares of educational institute is worth to land value. Finally, a lower percentage of vacant land tends to increase the residential land price

5.8.1.2 Local Regression Model: Residential Land Price

As identified above, the GWR model can examine the significance of the spatial variability of parameters. Based on the hypothesis that spatial effect, spatial heterogeneity, is present in the data. To illustrate these effects, the coefficients are interpolated by the inverse distance weighting method. The interpolated contour maps of the representative variables are shown in Figure 5 - 15 to Figure 5 - 20 where the coefficients were at each observation point. Obviously, the coefficients vary substantially.

Firstly, the result from global regression (OLS) indicated that larger distance station proximity does not reduce residential land value, but in Figure 5 - 15 shows that there are some areas where the shorter distance to station, the more valuable they are, reflected by negative coefficient in such blue areas. In addition, the premium is approximately 15,000 baht/sq.m per kilometer or US$ 500 per kilometers closer to the station. In these areas, there are rapid developments as can be seen by the continuous rise of new high-rise building especially luxury condominium and apartment due to the highly convenient access to the urban rail transit lines. On the other hand, the coefficient is positive in the red areas, meaning that although the distance to station is large, the price is still not decreasing because the access to the station is based on the other mode than walk.

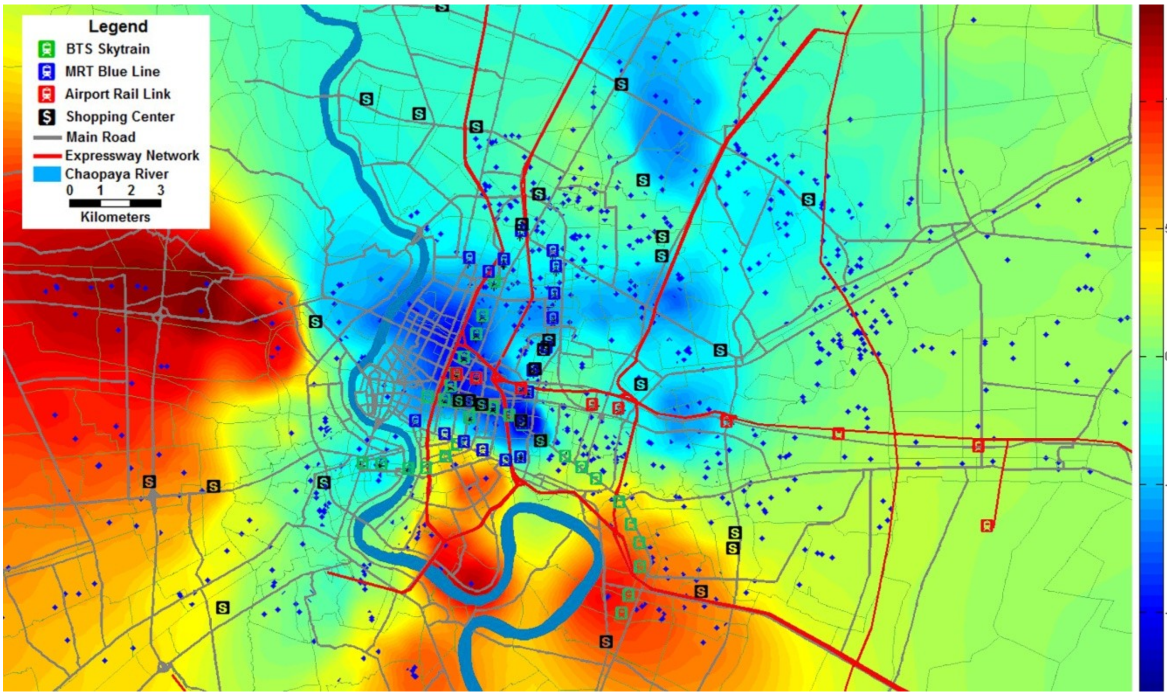

Figure 5 - 15 Coefficient Effects of Distance to Rail Transit Station to Residential Land Price

According to the result of the OLS model, it found that the better access to main road increases land value. In Figure 5 - 16, the coefficients of distance to main road variable estimated were shown as different color depending on each area. For example, the red and orange areas where the closer to the main road can add value around 5,000 baht/sq.m per kilometer US$ 127.5 per kilometer to 10,000 baht/sq.m per kilometer or US$ 335 per kilometer, respectively. On the other hand, every kilometer closer to main road raises the value of residential land in the blue areas by over 30,000 baht/sq.m or US$ 1,000.

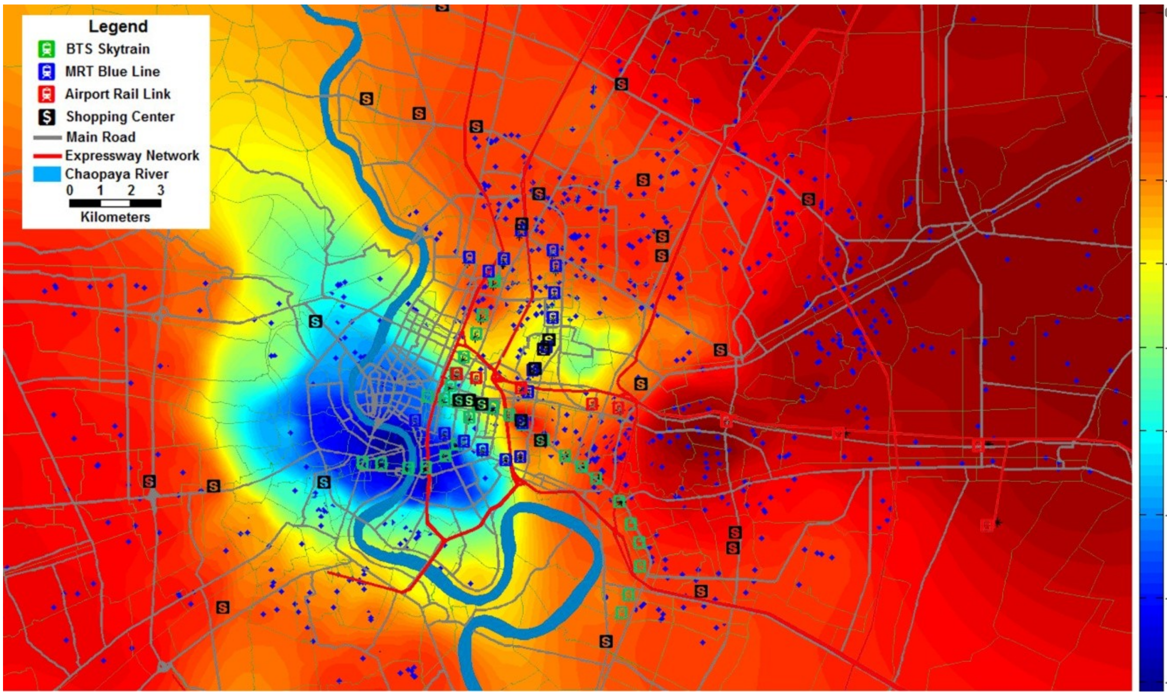

Figure 5 - 16 Coefficient Effects of Distance to Main Road to Residential Land Price

Next, Figure 5 - 17, the local coefficients of access point to an expressway ramp variable estimated was shown as different color points. It found the coefficients are negative in shades of blue where most of them are located in urban fringe and suburban and also known as a high-density residential area. Due to the fact that most people in Bangkok travel by their private car, hence, using the expressway is the best way to reduce the travel time. Therefore, better access to expressway can add value to the residential land price from 2,000 baht/sq.m per kilometer or US$ 70 per kilometer to 8,800 baht/sq.m per kilometer or US$ 270 per kilometer. In contrast, the coefficients were found a dis-benefit from being near the urban rail transit corridors and the CBD, indicated by positive sign in shades of red. These results could be indicating that if the rail transit network is served, the mode choice will be shifted to public transport.

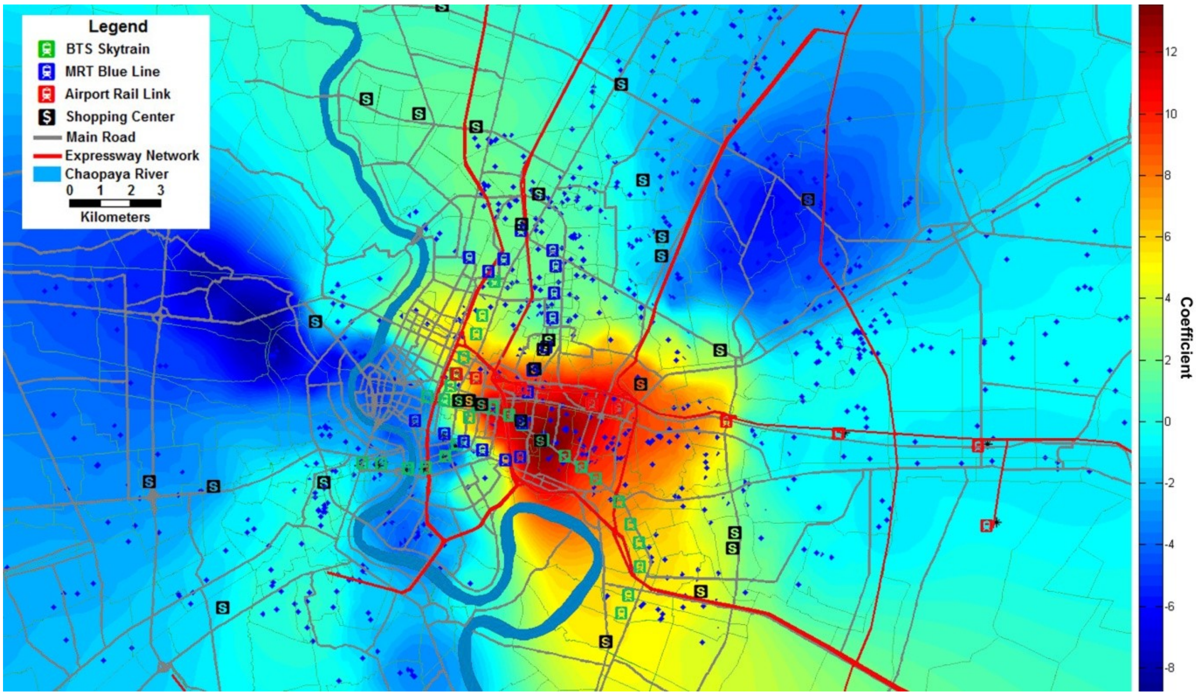

Figure 5 - 17 Coefficient Effects of Distance to Expressway Access to Residential Land Price

Next, closer look at the variation of the coefficient zonal median income in Figure 5 - 18 found that the residential value is sensitive to zonal median income in the red areas, where there are outer areas of Bangkok Metropolitan Region. It can add value around 10,000 baht/sq.m or US$ 336 for every 10,000 baht/month or US$ 336 increases. The reason behind this positive relationship to land price, that is, housing development, especially luxury housing has been rapidly increasing in these areas. Furthermore, it can be seen that some adjacent areas near BTS Skytrain such as Saphan Khwai station, Phaya Thai station and some adjacent areas of MRT Blue Line such as Suthisan station, Huai Khwang station where, there are rapid developments as can be seen by the continuous rise of new high-rise building especially luxury condominium and apartment, also have strongly impact of the zonal median income to the price of residential land. These results imply that high income households are more likely to live in condominium or apartment near the stations or prefer to live in single-detached housing in outer area.

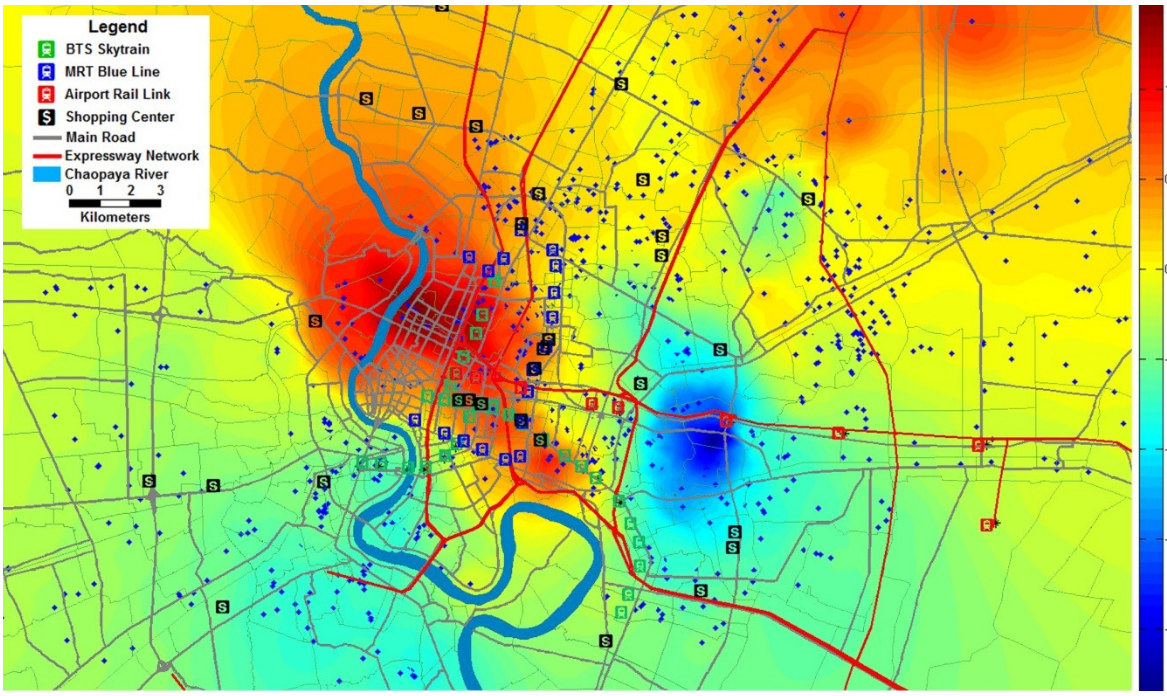

Figure 5 - 18 Coefficient Effects of Median Income to Residential Land Price

For the effects of road area to residential land price, the variations of the coefficient were illustrated in Figure 5 - 19. It found that the coefficient has negative impact in the inner areas as illustrated in blue color. Perhaps, a higher proportion of residential construction permits tend to raise residential congestion and traffic volume which is probably caused of unsafe, e.g., crowed and traffic accident. Conversely, most outer areas reveal the positive impact of road areas to residential land price. The reason that is transportation in Bangkok Metropolitan Region is presently based on road. Such relationship will add value from 20,000 baht/sq.m or US$ 670 to 40,000 baht/sq.m or US$ 1,340 for every one square kilometer of road areas larger.

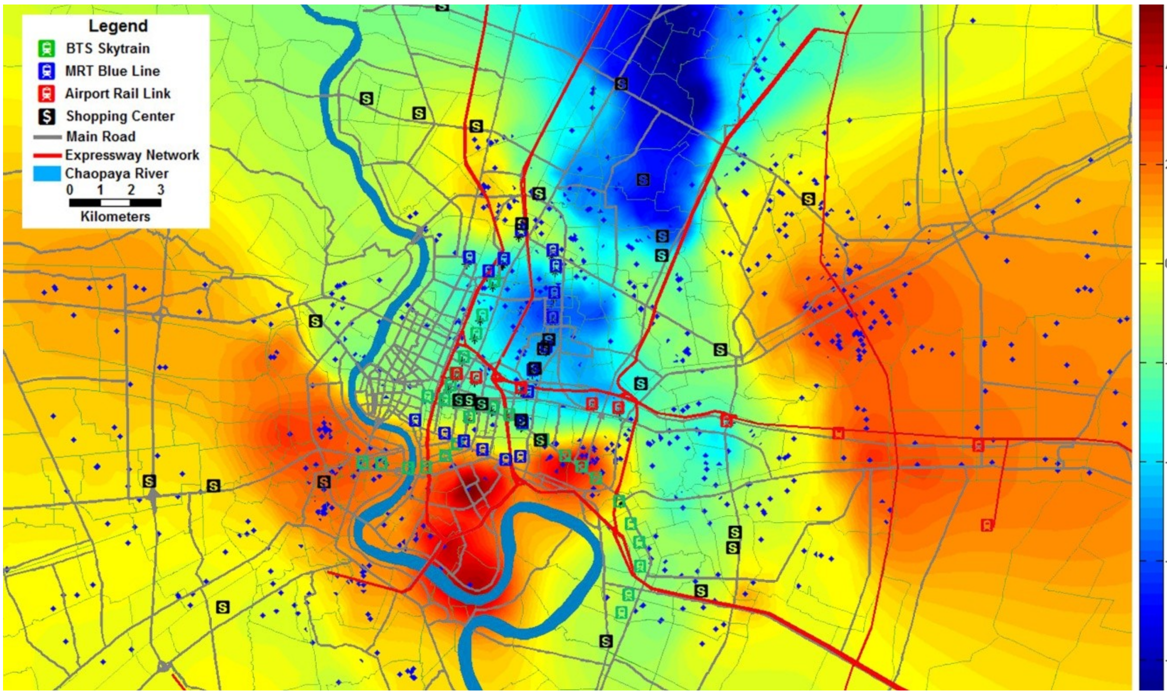

Figure 5 - 19 Coefficient Effects of Road Areas to Residential Land Price

Finally, the coefficient variations of sidewalk areas to residential land price were shown in the Figure 5 - 20. It has positive impact to the residential land price in the red areas but the extent of the impact is pronouncedly strong in the Asoke station, a transfer station of BTS Skytrain and MRT Blue Line, and in some adjacent areas along the urban rail transit corridors where walk is the important mode of access to transportation. On the other hand, it has negative impact (e.g. the blue areas) in the outer area and some adjacent areas of urban rail transit corridors where the other motorized modes dominate. However, three stations of BTS Skytrain, namely Thong Lo station, Phra Kanong station and Ekkamai station were found both road and sidewalk areas have positive impact to land value. In addition, both motorized and non-motorized are the important access modes among three stations.

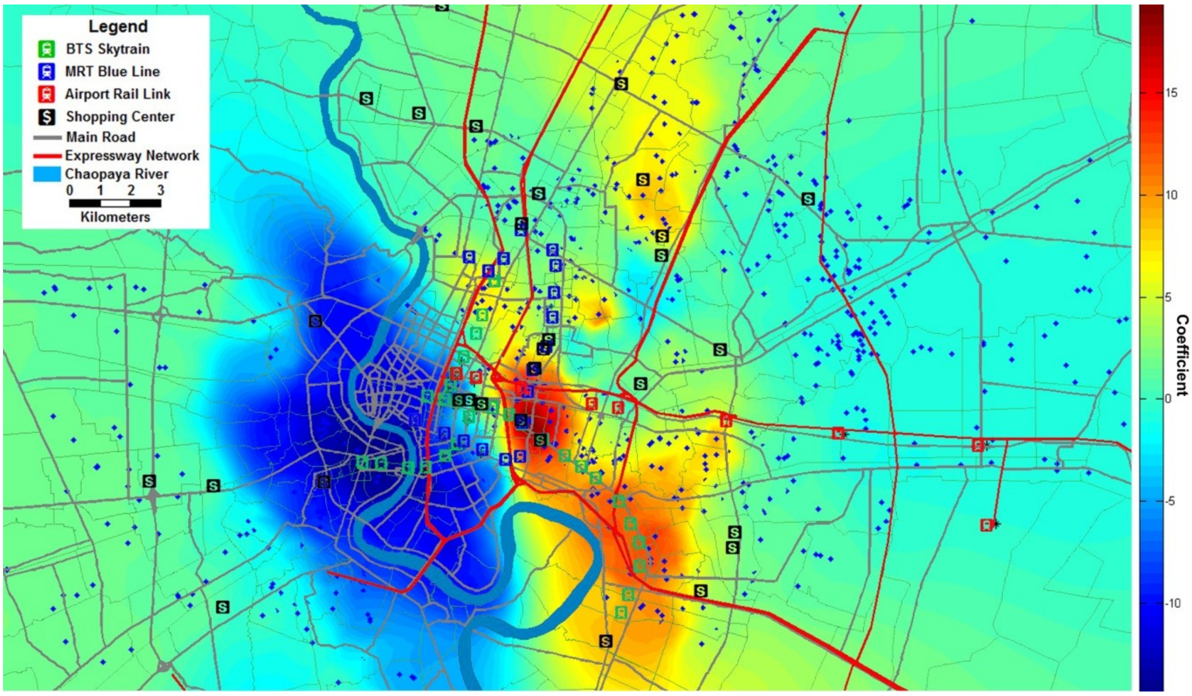

Figure 5 - 20 Coefficient Effects of Sidewalk Areas to Residential Land Price

5.8.2 Land Price Model: Non-Residential Land Parcel

Findings from the non-residential land value modeling, which were calibrated by the ordinary least squares (OLS) and geographically weight regression (GWR) method, are presented in Table 5 - 6, respectively. The GWR model gives local parameter estimates for each observation points, i.e., a total of 443 sets of estimates are obtained. However, in Table 5 - 6 shows only minimum, maximum, and average values. The estimation framework is the same trend as global regression (OLS model). The independent variables used to estimate the price model were divided into four categories: local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute. After extensive experimentations with different specifications, all models were chosen based on the theoretical and statistical significance of the estimated parameters.

Table 5 - 6 Non-Residential Land Price Model: Global Regression Model (OLS) and Local Regression Model (GWR)

Variables	OLS				GWR				
	Parameter	t-Statistic	P-value		Min	Max	Mean	P-value	
Local transportation accessibility									
DIST_STA	6.6201	2.9707	0.0030	***	-75.7067	41.8092	-5.5303	0.0000	***
DIST_MR	-2.2460	-2.9121	0.0040	***	-41.5455	0.2977	-12.5873	0.0000	***
DIST_EXP	1.4610	0.6886	0.4910	n/s	-21.4511	89.1028	-27.0425	0.0000	***
Work and non-work accessibility									
DIST_CBD	-4.0973	-1.9199	0.0560	*	-67.6543	17.5402	-13.4163	0.0000	***
DIST_SHOPPING	0.1715	0.0632	0.9500	n/s	-24.7195	53.7425	10.1391	0.0000	***
Neighborhood amenity									
MED_INC	2.7297	4.5216	0.0000	***	-1.1210	7.9123	1.8005	0.0500	**
EMP_DENS	0.3867	3.5478	0.0000	***	-0.0763	3.8454	0.6034	0.0000	***
Land attribute									
%_RESI_LAND	0.7777	1.7709	0.0770	*	-2.8728	2.9944	-0.2864	0.5600	n/s
%_COM_LAND	6.9005	9.0881	0.0000	***	-2.5049	13.1959	4.7019	0.0000	***
%_INDUS_LAND	1.5175	0.5196	0.6040	n/s	-24.6138	83.6217	15.2003	0.0000	***
%_EDUC_LAND	0.6857	0.3883	0.6980	n/s	-14.3052	9.7029	-0.5274	0.3300	n/s
%_VAC_LAND	-0.6572	-1.0056	0.3150	n/s	-6.1877	4.7454	-0.9475	0.1300	*
A_ROAD	1.5406	1.6449	0.1010	*	-11.3454	10.7832	-0.3675	0.0000	***
A_SIDEWALK	4.5930	2.3386	0.0200	**	-30.4829	26.4445	-3.2047	0.0000	***
R^2	0.5120				0.7299				
AIC	2,980.5299				2,881.2487				
RSS	20,103.1924				11,122.6052				

*** = significant at 1% level
** = significant at 5% level
* = significant at 10% level
n/s = no significant

From Table 5 - 6, the equation of land price model for non-residential land value is shown as follows;

OLS Model: 6.6201xDIST_STA – 2.2460xDIST_MR + 1.4610xDIST_EXP – 4.0973xDIST_CBD + 0.1715xDIST_SHOPPING + 2.7297xMED_INC + 0.3867xEMP_DENS + 0.7777x%_RESI_LAND + 6.9005x%COM_LAND + 1.5175x%INDUS_LAND + 0.6857x%EDUC_LAND – 0.6572x%_VAC_LAND + 1.5406xA_ROAD + 4.5930xA_SIDEWALK

GWR Model: – 5.5303xDIST_STA – 12.5873xDIST_MR – 27.0425xDIST_EXP – 13.4163xDIST_CBD + 10.1391xDIST_SHOPPING + 1.8005xMED_INC + 0.6034xEMP_DENS – 0.2864x%_RESI_LAND + 4.7019x%COM_LAND + 15.2003x%INDUS_LAND – 0.5274x%EDUC_LAND – 0.9475x%_VAC_LAND – 0.3675xA_ROAD – 3.2047xA_SIDEWALK

Let notice Table 5 - 6, with those statistically significant coefficients suggests that the GWR model has much better predictive powers than the OLS model, explaining around 73 percent of the variation in assessed prices among 443 parcels, which mainly consisted of single-detached housing and multi-attached housing. AIC in the GWR model is also lower than the OLS mode. With the residual sum of squares for both the GWR and the OLS being compared, the lower GWR residuals suggest that there is a significant improvement in the model fit when the GWR is adopted. The results of the final specification are discussed as below.

5.8.2.1 Global Regression Model: Non-Residential Land Price

For the OLS model, some independent variables, the attributes of each land parcel, had expected signs. However, the behavioral interpretations of non-residential land value are difference from residential land value. Among local transportation accessibility, straight line distance to main road (DIST_MR) has negative as expected, meaning that non-residential land parcel being located near main road are more valuable than those being located far away from main road ,i.e., new commercial development is encouraged along the road network. Such premium is probably due to good access opportunities. Nevertheless, the distance to rail transit station and expressway entrance access have positive coefficient. Although, the distance is too far, the land price is not decrease.

Among work and non-work accessibility, two independent variables, distance to CBD (DIST_CBD) and shopping mall or shopping center (DIST_SHOP), were used to investigate. Only distance to CBD variable shows the negative sign. This result means that the non-residential land parcels with greater accessibility to central business district (CBD) is more expensive, in the other word, this proxy variable represents the closeness to the city center, i.e., farther residential parcels are again cheaper. Conversely, the parameter of distance to shopping center or shopping mall shows the positive sign, meaning that although the distance to shopping center or shopping mall is large, the price is still not decreasing. Perhaps, the distance to the shopping center or shopping mall will not be the primary factor directly driving up land price. This variable shows the difference between the influencing factors on residential land value and non-residential land value.

For neighborhood amenity, two independent variables, median income (MED_INC) and employment density (EMP_DENS) were used to estimate non-residential land price model. The result shows that non-residential land parcels gain a higher premium, as the median income of zone increases. In fact, it is more likely for luxury housing development to occur where median income is high. Such sites attract for commercial development that will follow new residential development to serve the additional population. Next, higher employment density also tends to increase non-residential land value.

For land attribute, the percentage of residential area tends to increase non-residential land value as expected. Land development can also be a sequential process in that commercial development will follow new residential development as explained. Thus, a large number of residential areas confer a premium on non-residential land value. This is another variable that shows the difference between the influencing factors on residential land value and non-residential land value. Furthermore, a higher proportion of commercial area confers a premium on residential land value due to bid-rent completion, i.e., such neighborhoods can demand high price or rent. Likewise, a higher percentage of industrial area is also more likely to higher the value. Similarly, land parcel being located in area with higher shares of educational institute is worth to land value. Certainly, a lower percentage of vacant land tends to increase the residential land price. Finally, road areas tend to increase non-residential land value the same as sidewalk areas.

5.8.2.2 Local Regression Model: Non-Residential Land Price

As identified above, the GWR model can examine the significance of the spatial variability of parameters. Based on the hypothesis that spatial effect, spatial heterogeneity, is present in the data. To illustrate those effects, the coefficients are interpolated by the inverse distance weighting method. The interpolated contour maps of the representative variables are shown in Figure 5 - 21to Figure 5 - 26 where the coefficients were at each observation point. Obviously, the coefficients vary substantially.

Firstly, the result from global regression (OLS) indicated that larger distance station proximity does not reduce non-residential land value, but in Figure 5 - 21 shows that there are some areas where the shorter distance to station, the more valuable they are, reflected by negative coefficient in such blue areas. In addition, the premium is approximately 60,000 baht/sq.m per kilometer or US$ 2,500 per kilometers closer to the station. In these areas, there are rapid developments as can be seen by the continuous rise of new high-rise building especially office building and shopping mall due to the highly convenient access to the urban rail transit lines. On the other hand, the coefficient is positive in the red areas, meaning that although the distance to station is large, the price is still not decreasing because the access to the station is based on the other mode than walk.

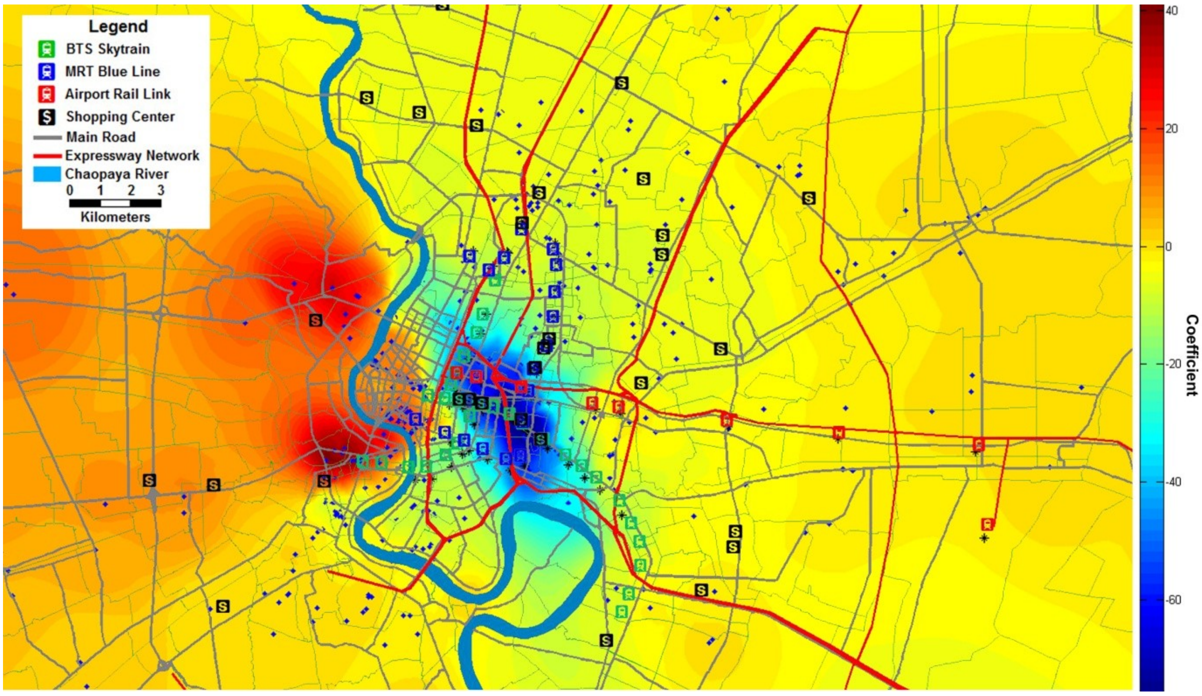

Figure 5 - 21 Coefficient Effects of Distance to Rail Transit Station to Non-Residential Land Price

According to the result of the OLS model, it found that the better access to main road increases land value. In Figure 5 - 22, the coefficients of distance to main road variable estimated were shown as different color depending on each area. In blue areas, it found the strongly impact of distance to main road on non-residential land price than other color areas. These areas are located in the old business city center of Bangkok Metropolitan Region where there are many small streets and alleys full of shops and vendors along the main road network. Such sites can high demand high price, i.e. every kilometer closer to main road raises the value of non-residential land in the blue areas by over 40,000 baht/sq.m or US$ 1,035. On the other hand, the red and orange areas where the closer to the main road can add value around 5,000 baht/sq.m per kilometer US$ 168 per kilometer to 15,000 baht/sq.m per kilometer or US$ 505 per kilometer, respectively.

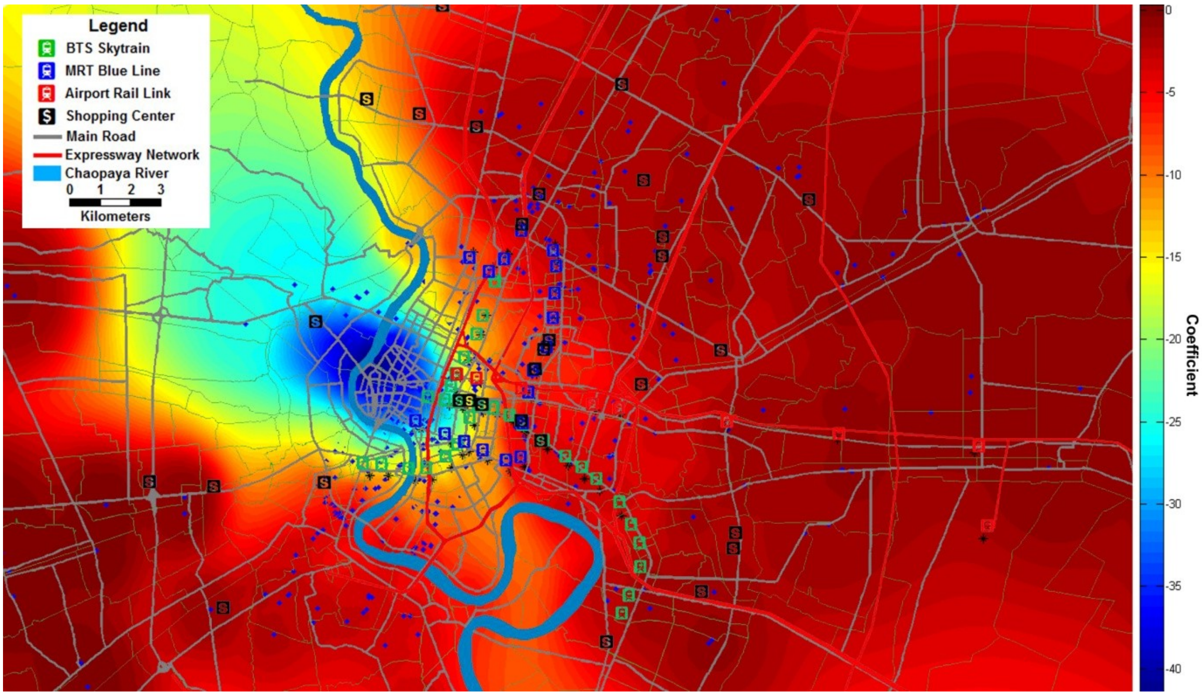

Figure 5 - 22 Coefficient Effects of Distance to Main Road to Non-Residential Land Price

Next, Figure 5 - 23, the local coefficients of access point to an expressway ramp variable estimated was shown as different color points. It found the coefficients are negative in shades of blue where most of them are located in urban fringe and suburban and also known as a high-density residential area. Due to the fact that most people in Bangkok travel by their private car, hence, using the expressway is the best way to reduce the travel time. Therefore, better access to expressway can add value to the non-residential land price from 10,000 baht/sq.m per kilometer or US$ 336 per kilometer to 20,000 baht/sq.m per kilometer or US$ 772 per kilometer. In contrast, the coefficients were found a dis-benefit from being near the urban rail transit corridors and the CBD, indicated by positive sign in shades of red.

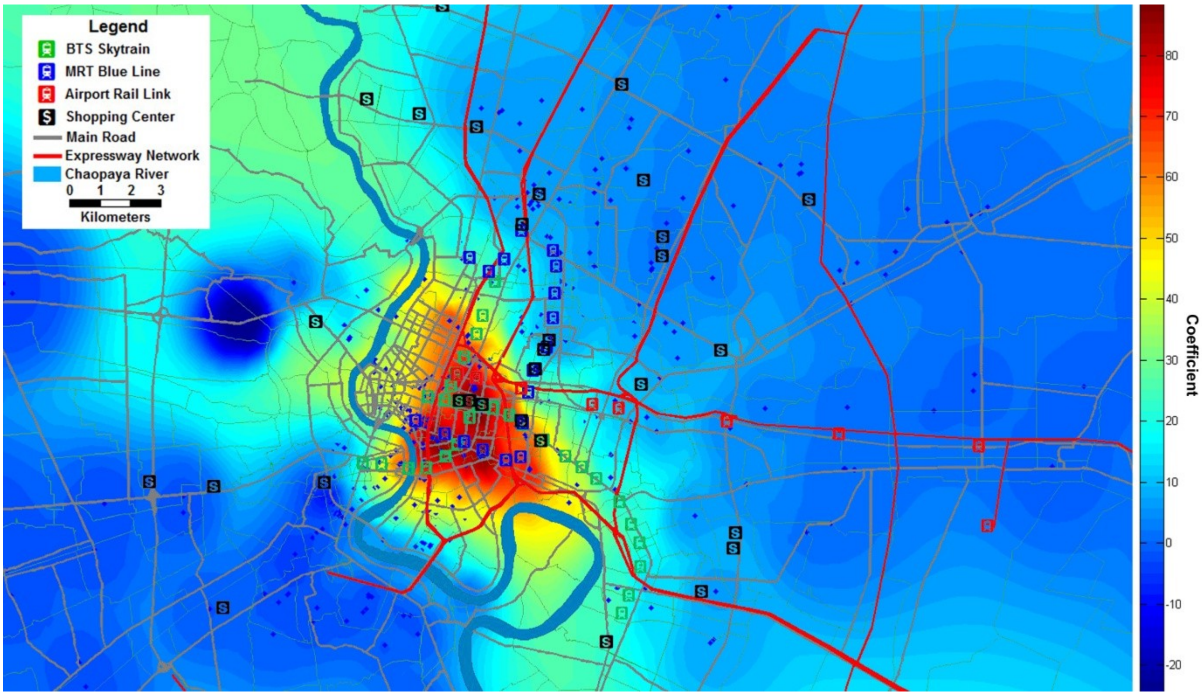

Figure 5 - 23 Coefficient Effects of Distance to Expressway Access to Non-Residential Land Price

Next, closer look at the variation of the coefficient zonal median income in Figure 5 - 24 found that the non-residential value is sensitive to zonal median income in the red areas, where there are inner areas of Bangkok Metropolitan Region. It can add value around 70,000 baht/sq.m or US$ 2,352.5 for every 10,000 baht/month or US$ 336 increases. However, most areas are illustrated in the blue color, indicating that although the zonal median income is small, the price is still not decreasing due to the benefit of being used for non-residential.

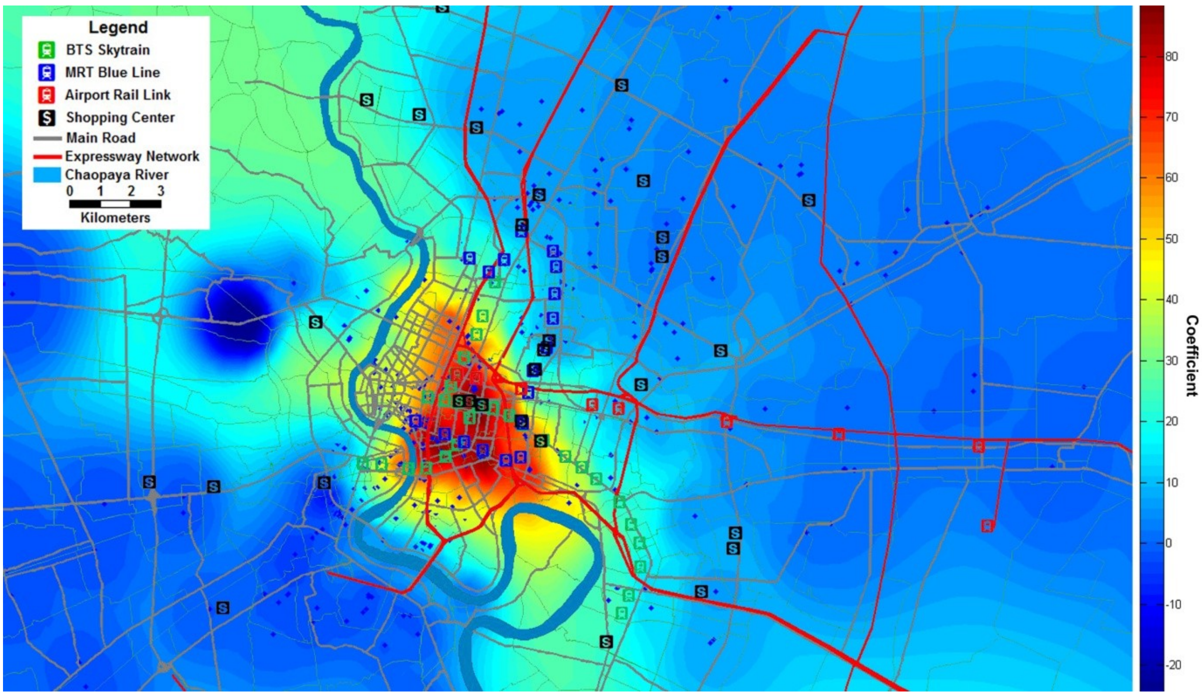

Figure 5 - 24 Coefficient Effects of Median Income to Non-Residential Land Price

For the effects of road area to non-residential land price, the variations of the coefficient were illustrated in Figure 5 - 25. It found that the coefficient has negative impact in the inner areas as illustrated in blue color. Perhaps, a higher proportion of residential construction permits tend to raise residential congestion and traffic volume which is probably caused of unsafe, e.g., crowed and traffic accident. Conversely, most outer areas reveal the positive impact of road areas to non-residential land price. The reason that is transportation in Bangkok Metropolitan Region is presently based on road. Such relationship will add value from 20,000 baht/sq.m or US$ 670 to 60,000 baht/sq.m or US$ 2,010 for every one square kilometer of road areas larger.

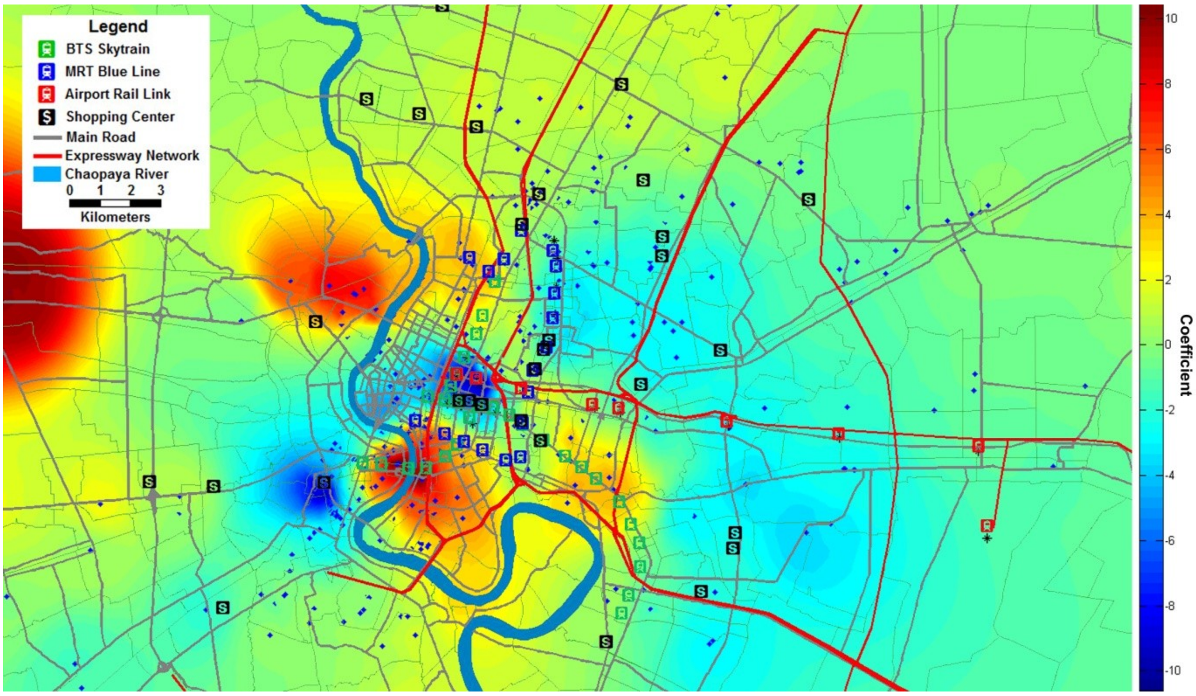

Figure 5 - 25 Coefficient Effects of Road Areas to Non-Residential Land Price

Finally, the coefficient variations of sidewalk areas to non-residential land price were shown in the Figure 5 - 26. It has positive impact to the residential land price in the red areas but the extent of the impact is pronouncedly strong in the Asoke station, a transfer station of BTS Skytrain and MRT Blue Line, and in some adjacent areas along the urban rail transit corridors where walk is the important mode of access to transportation. This result is similar to the effect of sidewalk to residential land parcel. Thus, this support that non-motorized mode is dominant at surrounding areas of those stations. On the other hand, it has negative impact (e.g. the blue areas) in the outer area and some adjacent areas of urban rail transit corridors where the other motorized modes dominate.

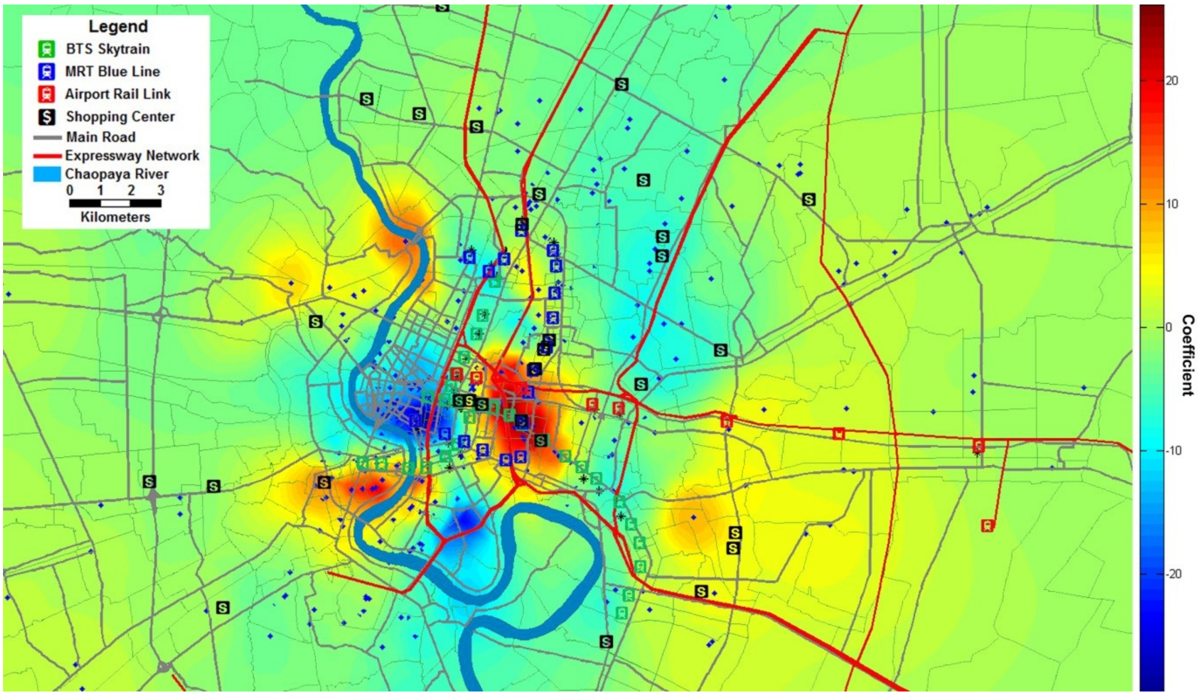

Figure 5 - 26 Coefficient Effects of Sidewalk Areas to Non-Residential Land Price

5.9 Effects of Urban Rail Transit Investment on Land Price

This section intends to measure of benefits of urban rail transit infrastructure in studies of public infrastructure capital. In the context of this section, wider benefits refer to the benefits beyond the geographic region in which the investment is undertaken. Since capitalization effects were thought to vary by urban rail transit corridor, the analysis in this section will be stratified to measures difference in land price impacts for the three existing urban rail transit in Bangkok Metropolitan region: BTS Skytrain, MRT Blue Line and Airport Rail Link.

To measure the capitalization effects of urban rail transit investment, the effects of the relative influence of proximity to each urban rail transit by exposing the coefficients used with each dummy variable for straight line distance intervals to the existing rail transit system: BTS Skytrain, MRT Blue Line and Airport Rail Link. The capitalization effects of residential land parcel and non-residential land parcel are presented in Table 5 - 7 and Table 5 - 8, respectively.

The two tables estimate all variables used in the previous section in order to controlling the effects of urban rail transit and other factors. Notably, Table 5 - 7 and Table 5 - 8 explain around 55 percent of the variation in assessed prices among 925 parcels of residential land and 443 parcels of non-residential land. The results of the final specification are discussed as below.

In addition, from Table 5 - 7 to Table 5 - 8, the equations of land price model by distance intervals among urban rail transit lines can be written as follows;

Table 5 - 7 Residential Land Price Model by Distance Intervals among Existing Urban Rail Transit Network

Variables	BTS Skytrain			MRT Blue Line			Airport Rail Link		
	Parameter	Standardized	t-Statistic	Parameter	Standardized	t-Statistic	Parameter	Standardized	t-Statistic
Local transportation accessibility									
DIST_STA0.5	2.8612	0.1264	4.8306	2.8938	0.1037	4.1525	-1.8177	-0.0506	-2.1044
DIST_STA1	1.4689	0.0924	3.4410	1.6539	0.1031	4.1148	-0.9852	-0.0426	-1.7638
DIST_STA1.5	0.8419	0.0497	1.9517	0.9112	0.0562	2.1593	0.2205	0.0114	0.4749
DIST_STA2	0.2514	0.0142	0.5662	-0.6113	-0.0377	-1.5169	0.4620	0.0282	1.1415
DIST_MR	-0.2445	-0.0578	-2.0011	-0.2763	-0.0653	-2.2739	-0.2817	-0.0666	-2.2706
DIST_EXP	-0.0344	-0.0043	-0.0889	-0.1285	-0.0159	-0.3320	-0.0545	-0.0067	-0.1393
Work and non-work accessibility									
DIST_CBD	-0.3113	-0.0582	-0.8531	-0.0862	-0.0161	-0.2328	-0.5374	-0.1004	-1.4707
DIST_SHOPPING	-0.3692	-0.0320	-0.7068	-0.2292	-0.0199	-0.4457	-0.0940	-0.0091	-0.1794
Neighborhood amenity									
MED_INC	0.2529	0.0492	1.6481	0.2272	0.0442	1.4834	0.2077	0.0404	1.3414
EMP_DENS	0.1052	0.0368	1.2598	0.0336	0.0117	0.3826	0.2052	0.0717	2.3857
Land attribute									
%_RESI_LAND	-0.7825	-0.2746	-6.3353	-0.6895	-0.2420	-5.4776	-0.7853	-0.2756	-6.2877
%_COM_LAND	4.0582	0.5470	12.6563	4.5873	0.6183	14.2707	4.2312	0.5703	13.0100
%_INDUS_LAND	-4.2581	-0.1795	-6.6738	-4.5932	-0.1936	-7.3032	-4.8453	-0.2042	-7.5398
%_EDUC_LAND	3.1573	0.2325	5.1778	4.4682	0.3290	7.7642	4.1625	0.3065	7.1731
%_VAC_LAND	0.2324	0.0773	1.7112	0.3396	0.1130	2.4907	0.2631	0.0875	1.9165
A_ROAD	-0.9308	-0.1486	-3.8363	-1.5496	-0.2474	-6.6452	-1.3562	-0.2165	-5.8069
A_SIDEWALK	0.2637	0.0328	0.8653	0.4742	0.0589	1.5737	0.4885	0.0607	1.5753
R^2		0.5228			0.5281			0.5213	
AIC		4,309.9265			4,299.5613			4,089.4933	
RSS		5,482.4523			5,421.3608			5,603.1414	

Table 5 - 8 Non-Residential Land Price Model by Distance Intervals among Existing Urban Rail Transit Network

Variables	BTS Skytrain			MRT Blue Line			Airport Rail Link		
	Parameter	Standardized	t-Statistic	Parameter	Standardized	t-Statistic	Parameter	Standardized	t-Statistic
Local transportation accessibility									
DIST_STA0.2	12.2761	0.1472	4.3269	4.1680	0.0500	1.4481	2.0397	0.0142	0.4156
DIST_STA0.4	1.5094	0.0244	0.7039	3.5636	0.0837	2.3452	-6.8398	-0.0749	-1.8410
DIST_STA0.6	-1.4362	-0.0232	-0.6709	-2.7904	-0.0488	-1.3956	-4.4731	-0.0753	-1.8054
DIST_STA0.8	-3.3842	-0.0779	-2.0467	-2.3439	-0.0528	-1.5028	-1.9454	-0.0233	-0.6774
DIST_MR	-1.7449	-0.0952	-2.3037	-1.8321	-0.9999	-2.3894	-1.8684	-0.1019	-2.4148
DIST_EXP	2.0426	0.0741	0.0993	2.5704	0.0932	1.2402	2.7997	0.1015	1.3439
Work and non-work accessibility									
DIST_CBD	-1.4239	-0.0877	-0.7132	-2.1084	-0.1299	-1.0597	-2.1726	-0.1338	-1.0818
DIST_SHOPPING	2.4033	0.0612	0.9108	1.8916	0.0482	0.7061	1.7450	0.0444	0.6490
Neighborhood amenity									
MED_INC	3.0380	0.2402	4.9416	2.8671	0.2267	4.7439	2.6371	0.2085	4.2934
EMP_DENS	0.4824	0.1739	4.2515	0.3648	0.1315	3.3059	0.5941	0.2141	4.2311
Land attribute									
%_RESI_LAND	0.6355	0.0845	1.4791	0.6344	0.0844	1.4523	0.5170	0.0688	1.1688
%_COM_LAND	6.6557	0.5613	8.8427	6.9185	0.5835	9.0716	6.2456	0.5267	7.9614
%_INDUS_LAND	-0.3828	-0.0060	-0.1310	0.9188	0.0145	0.1352	0.3497	0.0055	0.1180
%_EDUC_LAND	0.7011	0.0219	0.3994	0.4469	0.0139	0.2489	0.4404	0.0137	0.2471
%_VAC_LAND	-0.5071	-0.0559	-0.7779	-0.3650	-0.0403	-0.5541	-0.5675	-0.0626	-0.8581
A_ROAD	1.2044	0.0671	1.2943	1.3900	0.0774	1.4930	1.0551	0.0588	1.1258
A_SIDEWALK	1.5793	0.0536	0.9195	2.1392	0.0726	1.2285	1.7925	0.0608	1.0218
R^2		0.5301			0.5164			0.5083	
AIC		2,970.3257			2,982.9755			2,990.3816	
RSS		19,358.413			19,919.156			20,254.964	

For residential land price:

BTS Skytrain: 0.1264xDIST_STA0.5 + 0.0924xDIST_ STA1 + 0.0497xDIST_STA1.5 + 0.0142xDIST_STA2 – 0.0578xDIST_MR – 0.0043xDIST_EXP – 0.0582xDIST_CBD – 0.0320xDIST_SHOPPING + 0.0492xMED_INC + 0.0368xEMP_DENS – 0.2746x%_RESI_LAND + 0.5470x%COM_LAND – 0.1795x%INDUS_LAND + 0.2325x%EDUC_LAND + 0.0773x%VAC_LAND – 0.1486xA_ROAD + 0.0328xA_SIDEWALK

MRT Blue Line: 0.1037xDIST_STA0.5 + 0.1031xDIST_ STA1 + 0.0562xDIST_STA1.5 – 0.0377xDIST_STA2 – 0.0653xDIST_MR – 0.0159xDIST_EXP – 0.0161xDIST_CBD – 0.0199xDIST_SHOPPING + 0.0442xMED_INC + 0.0117xEMP_DENS – 0.2420x%_RESI_LAND + 0.6183x%COM_LAND – 0.1936x%INDUS_LAND + 0.3290x%EDUC_LAND + 0.1130x%VAC_LAND – 0.2474xA_ROAD + 0.0589xA_SIDEWALK

Airport Rail Link: – 0.0506xDIST_STA0.5 – 0.0426xDIST_ STA1 + 0.0114xDIST_STA1.5 + 0.0282xDIST_STA2 – 0.0666xDIST_MR – 0.0067xDIST_EXP – 0.1004xDIST_CBD – 0.0091xDIST_SHOPPING + 0.0404xMED_INC + 0.0717xEMP_DENS – 0.2756x%_RESI_LAND + 0.5703x%COM_LAND – 0.2042x%INDUS_LAND + 0.3065x%EDUC_LAND + 0.0875x%VAC_LAND – 0.2165xA_ROAD +0.0607xA_SIDEWALK

For non-residential land price:

BTS Skytrain: 0.1472xDIST_STA0.2 + 0.0244xDIST_ STA0.4 – 0.0232xDIST_STA0.6 – 0.0779xDIST_STA0.8 – 0.0952xDIST_MR + 0.0741xDIST_EXP – 0.0877xDIST_CBD + 0.0612xDIST_SHOPPING + 0.2402xMED_INC + 0.1739xEMP_DENS + 0.0845x%_RESI_LAND + 0.5613x%COM_LAND – 0.0060x%INDUS_LAND + 0.0219x%EDUC_LAND – 0.0559x%VAC_LAND + 0.0671xA_ROAD + 0.0536xA_SIDEWALK

MRT Blue Line: 0.0500xDIST_STA0.2 + 0.0837xDIST_ STA0.4 – 0.0488xDIST_STA0.6 – 0.0528xDIST_STA0.8 – 0.9999xDIST_MR + 0.0932xDIST_EXP – 0.1299xDIST_CBD + 0.0482xDIST_SHOPPING + 0.2267xMED_INC + 0.1315xEMP_DENS + 0.0844x%_RESI_LAND + 0.5835x%COM_LAND + 0.0145x%INDUS_LAND + 0.0139x%EDUC_LAND – 0.0403x%VAC_LAND + 0.0774xA_ROAD + 0.0726xA_SIDEWALK

Airport Rail Link: 0.0142xDIST_STA0.2 – 0.0749xDIST_ STA0.4 – 0.0753xDIST_STA0.6 – 0.0233xDIST_STA0.8 – 0.1019xDIST_MR + 0.1015xDIST_EXP – 0.1338xDIST_CBD + 0.0444xDIST_SHOPPING + 0.2085xMED_INC + 0.2141xEMP_DENS + 0.0688x%_RESI_LAND + 0.5267x%COM_LAND + 0.0555x%INDUS_LAND + 0.0137x%EDUC_LAND – 0.0626x%VAC_LAND + 0.0588xA_ROAD + 0.0608xA_SIDEWALK

5.9.1 Effects of Urban Rail Transit on Residential Land Price by Distance Intervals

Controlling the other predictors, Figure 5 - 27 presents the capitalization effects of residential land parcels being near the stations of BTS Skytrain, MRT Blue Line and Airport Rail Link. The distance ring that provides the best statistical fits is the distance to the stations within 0.5 kilometers bands up to 2 kilometers.

Figure 5 - 27 derived from the standardized coefficients of the distance to the stations of BTS skytrain, MRT Blue Line and Airport Rail Link for four 500-meter bands (relative to land parcels beyond 2 kilometers of straight-line distance to the stations). Firstly, I will discuss about the capitalization effects of BTS Skytrain and MRT Blue Line due to the types of operation is quite similar and then I will interpret the beneficial effects of Airport Rail Link.

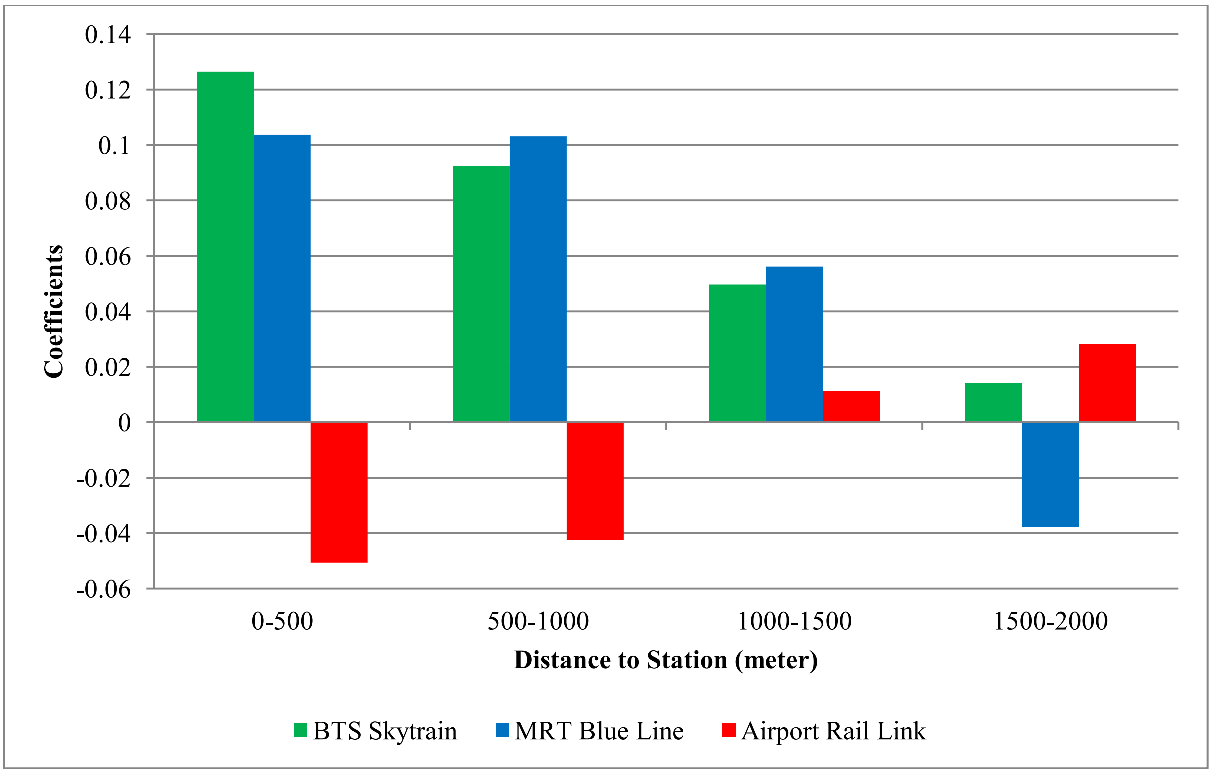

Figure 5 - 27 Coefficient Effects of Urban Rail Transit on Residential Land Price by Distance Intervals among Existing Urban Rail Transit

The figure clearly shows that the beneficial effects of proximity to BTS Skytrain stations and MRT Blue Line stations eroded with distance, within 2 kilometers bands. A 100,000 baht/sq.m (US$ 3,360) land parcel that is located within 0.5 kilometer of BTS Skytrain will be priced 13,000 baht/sq.m (US$ 436) more than an identical property that is located far from the BTS Skytrain station. Specifically, residential land parcels being within 0.5 kilometer of BTS Skytrain were worth around 12 percent more per square meter but were worth 9 percent per square meter within 0.5 kilometer to 1 kilometer and less than 6 percent within 1 kilometer to 1.5 kilometers. On the other hand, residential land parcels lying within 1 kilometer of MRT Blue Line stations were worth around 10 percent and less than 6 percent within 1 kilometer to 1.5 kilometers. For example, an 113,000 baht/sq.m (US$ 3,794) land parcel that is located within 0.5 kilometer of BTS Skytrain will be worth around 111,000 baht/sq.m (US$ 3,692.5) if this parcel is located within 0.5 kilometer of MRT Blue Line. However, residential land parcels lying at 0.5 kilometer to 1.5 kilometers of MRT Blue Line will be priced slightly higher than land within 0.5 kilometer to 1.5 kilometers of BTS Skytrain. At 1.5 kilometer to 2 kilometer, it found that only the proximity to BTS Skytrain station is still impact on the residential land value.

However, the capitalization effects of proximity to Airport Rail Link stations are complicated. It found that the beneficial effects will worth less than 4 percent to residential land parcels being within 1 kilometer to 2 kilometer of Airport Rail Link but it seems no effect to parcels lying within 1 kilometer from Airport Rail Link stations. This reason that is undeveloped land parcels were more likely to convert to residential land parcel relative to parcels more than 1 kilometer away from stations. Therefore, such converts will be adding premium value for residential use at 1 kilometer from the station.

5.9.2 Effects of Urban Rail Transit on Non-Residential Land Price by Distance Intervals

Controlling the other predictors, Figure 5 - 28 presents the capitalization effects of residential land parcels being near the stations of BTS Skytrain, MRT Blue Line and Airport Rail Link. The distance ring that provides the best statistical fits is the distance to the stations within 0.2 kilometers bands up to 0.8 kilometers.

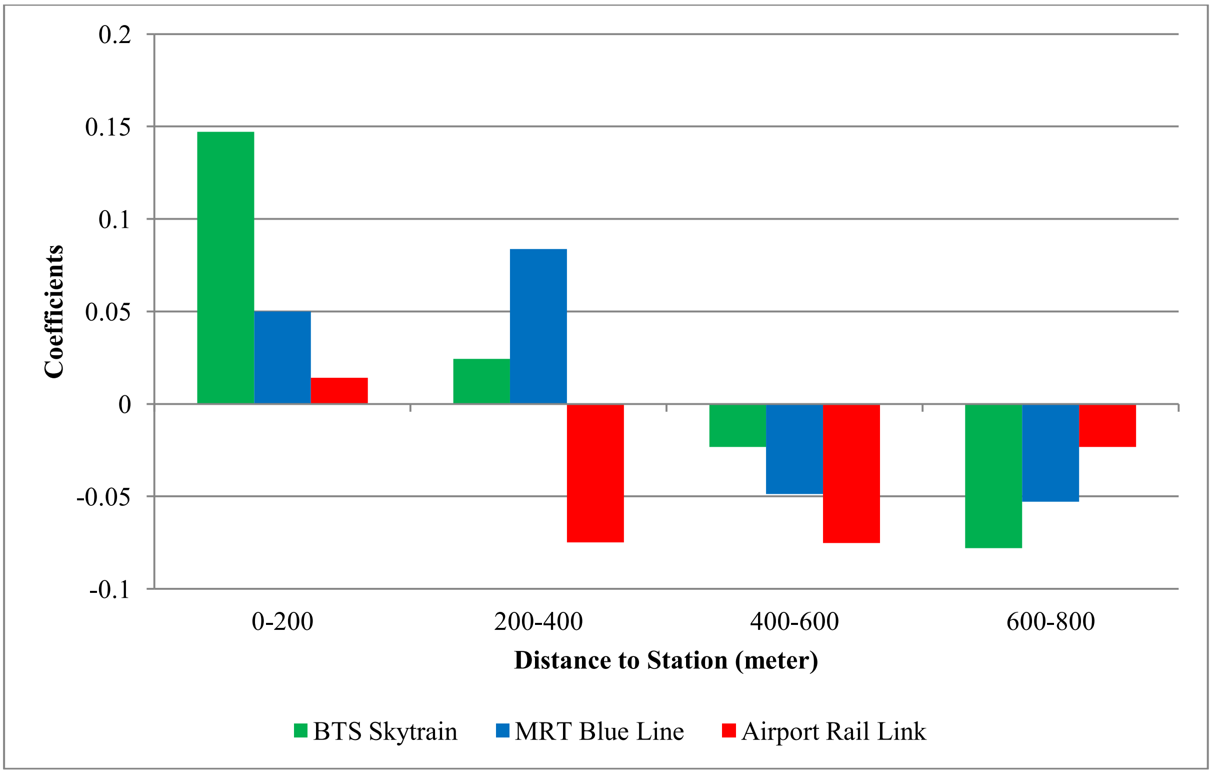

Figure 5 - 28 Coefficient Effects of Urban Rail Transit on Non-Residential Land Price by Distance Intervals among Existing Urban Rail Transit

Figure 5 - 28 derived from the standardized coefficients of the distance to the stations of BTS skytrain, MRT Blue Line and Airport Rail Link for four 200-meter bands (relative to land parcels beyond 0.8 kilometers of straight-line distance to the stations). Firstly, I will discuss about the capitalization effects of BTS Skytrain and MRT Blue Line due to the types of operation is quite similar and then I will interpret the beneficial effects of Airport Rail Link.

The figure clearly shows that the beneficial effects of proximity to BTS Skytrain stations and MRT Blue Line stations eroded with distance, within 1 kilometer bands. Specifically, non-residential land parcels being within 0.2 kilometer of BTS Skytrain were worth around 15 percent more per square meter but were worth less than 5 percent per square meter within 0.2 kilometer to 0.4 kilometer. For example, a 100,000 baht/sq.m (US$ 3,360) land parcel that is located within 0.2 kilometer of BTS Skytrain will be priced 15,000 baht/sq.m (US$ 503.5) more than an identical property that is located far from the BTS Skytrain station. On the other hand, an 115,000 baht/sq.m (US$ 3,860) non-residential land parcel that is located within 0.2 kilometer of BTS Skytrain will be worth around 105,000 baht/sq.m (US$ 3,525) if this parcel is located within 0.2 kilometer of MRT Blue Line and roughly 3,000 baht/sq.m more than another identical property that is located within 0.2 kilometer to 0.4 kilometer from the stations, meaning that non-residential land parcels lying within 0.2 kilometer of MRT Blue Line were worth around 5 percent but being within 0.2 kilometer to 0.4 kilometer conferred higher premiums around 8 percent. This reason that is the changes of land use were more likely to convert to non-residential land parcel relative to parcels more than 0.2 kilometer away from stations. Therefore, such converts will be adding premium value for non-residential use at 0.2 kilometer from the station. However, non-residential land parcels lying far from 0.4 kilometer of the stations are not found the relationship to the distance interval to stations. Finally, the capitalization effects of proximity to Airport Rail Link stations found that the beneficial effects will worth less than

2.5 percent to non-residential land parcels being within 0.2 kilometer of Airport Rail Link but it seems no effect to parcels lying far from 0.2 kilometer from Airport Rail Link stations.

5.10 Summary

This chapter is to examine how the urban rail transit development influences land value. Firstly, I showed that the influence of the rail transit on residential property value is large; indicated by the increasing land price compared in each published year during 1996 to 2008. Then, land price models by classifying land price data into different groups of land use such as residential and non-residential obtained from the application of regression framework and it is, furthermore, accommodating the spatial effect, i.e., heterogeneity which is estimated based on the geographic weighted regression model (GWR). In addition, non-residential land uses in this chapter is the same as meaning in chapter 4, but residential land uses is grouped condominium and apartment (high-rise residential uses in chapter 4) into residential land uses category because of a small number of high-rise residential price data availability. In this chapter, the three existing urban rail transit namely BTS Skytrain, MRT Blue Line and Airport Rail Link were used measure the capitalization effects of land parcels being near the urban rail transit stations. However, the under construction line, i.e., MRT Purple Line is excluded due to lack of land price data availability.

As known, factor influencing land price are myriad and vary over space. One of the objective in this chapter focuses on the influencing factors in determining land price and incorporating the spatial effect. The important findings from the empirical analysis are as follows. Let's begin with the global regression model (OLS) of residential and non-residential land price. First, local transportation accessibility is associated with the land price. For example, land parcels both residential and non-residential uses being located near main road are more valuable than those being located farther away. Likewise, residential land parcels with greater accessibility to the expressway access is more expensive than farther residential parcels. Nevertheless, the distance to the expressways is too far, non-residential land price is not decrease. Likewise, only residential land parcels gains a higher premium as the distance to shopping center decreases. However, both residential and non-residential land parcels with greater accessibility to central business district (CBD) is more expensive, in the other word, this proxy variable represents the closeness to the city center, i.e., farther residential and non-residential parcels are again cheaper. Among the neighborhood amenity variables, they are also related to the land price however they occurred spatially differentiate. Next, land attribute, a higher percentage of industrial area and road pavement area is more likely to lower the residential land price. On the other hand, a higher proportion of commercial area confers a premium on residential and non-residential land value due to bid-rent completion. These results show the varying among the land use type in determining land price model.

Besides, the spatial effect, i.e., heterogeneity was accommodated to land price model. The model results found that the impact is quite complicated and varied over space. For example, in the OLS model indicated that larger distance station proximity does not reduce residential land price but local regression model (GWR) of residential and non-residential land price showed that there are some areas where the shorter distance to station, the more valuable they are. The premium for residential and non-residential land parcels is approximately 15,000 baht/sq.m per kilometer or US$ 500 per kilometers closer to the station and 60,000 baht/sq.m per kilometer or US$ 2,500 per kilometers closer to the station, respectively. Likewise, better access to expressway especially in outer areas can add value to the residential land price from 2,000 baht/sq.m per kilometer or US$ 70 per kilometer to 8,800 baht/sq.m per kilometer or US$ 270 per kilometer and non-residential land price from 10,000 baht/sq.m per kilometer or US$ 336 per kilometer to 20,000 baht/sq.m per kilometer or US$ 772 per kilometer. However, these effects were found a dis-benefit for residential and non-residential land parcels being near the urban rail transit corridors and the CBD.

Another objective of this chapter is to investigate the capitalization effects of urban rail transit on land price. The land price models indicated that the BTS Skytrain conferred benefit to residential land parcels approximately 15 percent at 500 meters from the stations and nearly 10 percent at 500 meters to 1 kilometer as indicated in Malaitham *et al.* (2013), while residential land parcels lying within 1 kilometer of the MRT Blue Line stations were worth around 10 percent and less than 6 percent within 1 kilometer to 1.5 kilometers. Next, the capitalization effects of proximity to Airport Rail Link stations are complicated. It found that the beneficial effects will worth less than 4 percent to residential land parcels being within 1 kilometer to 2 kilometer of Airport Rail Link but it seems no effect to parcels lying within 1 kilometer from Airport Rail Link stations. On the other hand, non-residential land parcels being within 0.2 kilometer of BTS Skytrain were worth around 15 percent more per square meter but were worth less than 5 percent per square meter within 0.2 kilometer to 0.4 kilometer, while non-residential land parcels lying within 0.2 kilometer of MRT Blue Line were worth around 5 percent but being within 0.2 kilometer to 0.4 kilometer conferred higher premiums around 8 percent. Finally, the capitalization effects of proximity to Airport Rail Link stations found that the beneficial effects will worth less than 2.5 percent to non-residential land parcels being within 0.2 kilometer of Airport Rail Link but it seems no effect to parcels lying far from 0.2 kilometer from Airport Rail Link stations.

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CHAPTER 6

IS THE EFFECT OF URBAN RAIL TRANSIT IMPORVEMENT ASSOCIATED WITH RESIDENTIAL LOCATION DECISION

This chapter presents the final objectives of this study that is whether the effect of urban rail transit development associated with residential location decision. In fact, there are many factors might contribute to differences in household residential location decision. However, many previous literatures indicated that transportation accessibility plays the important role in residential decision making. As known, the urban rail transit development provides a high level of access to other activities for households such as access to work, shopping, etc. The hypothesis, that is, improving in transportation accessibility will be reflected as the dominant factors for the residential location decision, i.e., exploring the role of urban rail transit lines in determining residential location decision. Traditional discrete choice models, namely multinomial logit (ML) and nested logit model (NL) were used to estimate in many substantial studies, furthermore, an application of discrete choice model for a ranking of alternatives, i.e., rank-ordered logit (ROL) and ranked-ordered nested logit (RONL) model were also applied to determine in this chapter. The mainly data used for this examining was obtained from a stated preference survey in Bangkok Metropolitan Region, Thailand incorporating with other variables such as local transportation accessibility, work and non-work accessibility, house affordability, neighborhood amenity and land attribute. Furthermore, another important point of this chapter is to examine the variations in sensitivity across the households to those attributes.

6.1 Background and Motivation

Housing is one of the most important basic needs for humans relating a particular way of living. A lot of people spend a much larger percentage of their income on housing in order to be satisfied with its amenities and attributes. Choosing a good place to live may seem like a challenging process. Will it be a studio condominium in the city center, an old house in need of repairs in the urban fringe or a new house with front yard in the suburban? Each of these choices might be appropriate for a certain individual, but they might not all be appropriate for the same person at the same point of life. Making a decision is trade-offs between housing amenities and location characteristics and a response to an extremely complex set of economic, social, lifestyle, attitude and preference. The first young couple might choose the one studio in the inner city while the second young couple might select the new house with front yard in the suburban because they need a green space and good air quality with quiet streets in the area they live. Therefore, choosing a neighborhood is almost as critical as choosing a house or apartment; it needs to be safe, affordable and provide everything that people need. It can be said that people are not buying a house but they are investing in a neighborhood. Besides, the transportation, the linkage among activities of households which are performed at different locations in the city, plays major role of residential location choice decisions in viewpoint of accessibility. Previous studies (Chapter 2) found that residential location choice is positively impacted by the availability of transit between the home and work zones in San Francisco Bay Area. As the number of commuters in the household who have transit connectivity increases, the likelihood of residential location in a zone increases as well. In contrast, a distance to railway station is less important for people preferring the car. The complexity of people's lives makes housing and location choice a decision is influenced by a variety of factors.

The BMR is still young to its urban rail transit history although three lines, consist of BTS Skytrain, MRT Blue Line, and Airport Rail Link, are now operating. An important function of any rail transit system is to provide for people accessibility to residences; places for employment, recreation, shopping and so on; and for public goods and services, accessibility to points of production and distribution. Consequently, it can refer that the structure and capacity of rail transit networks affect the level of accessibility. Then, the adjacent areas of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become the attractiveness areas for commercial developments and residential developments. Obviously, after first urban rail transit and others, e.g., BTS Skytrain, MRT Blue Line, and Airport Rail Link opened their service, the inventory of housing along the corridor of urban rail transit network is rapidly and explicitly expanding. As said, it claims that the locations where urban rail transit service availability tend to attract the moving made by household more than the locations where there are no network pass through. More recently, Bangkok Metropolitan Region in Thailand has developed a long-range transportation master plan and placed the top priority to urban rail transit investments. Those benefits due to rail transit development also impact on the areas which is announced future extension. Such benefits make integrated models of land use and transportation very relevant for prediction of future urban structures.

This research aims to improve upon model specification in residential location theory in the Bangkok Metropolis by expressing the importance of urban rail transit as a derivative of peoples' decision to reside near or along rail transit service availability. To analyze the effects of accessibility to each urban rail transit lines on residential location choices, this chapter relies on random utility theory to estimate discrete choice models of residential location decision making. This theory is based on the assumption that people choose residential locations that maximize their utilities. However, this chapter assumed that every household moves freely to any residential location without any constraints on housing availability. Thus, the residential location choice models used in this chapter do not reflect housing supply and availability.

6.2 Objective and Approach

The objective of this chapter is to the role of urban rail transit lines in determining residential location decisions. To get the target goal, the key approaches were performed as below;

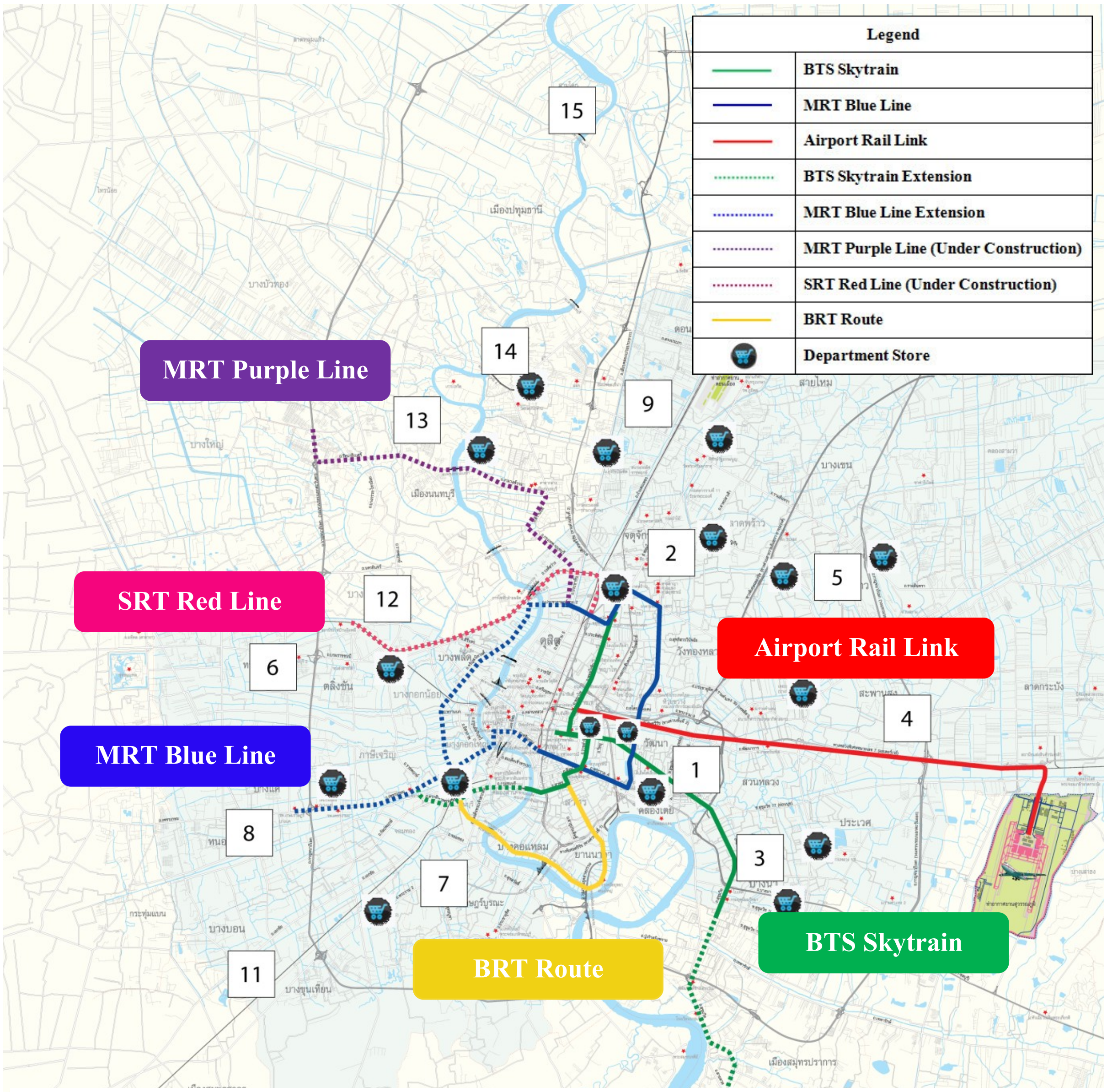
- First is to explore the important factors during the residential decision-making process among household income and travel modes.
- Second is to analyze households' tradeoffs in the decision among alternative housing choices.
- Third is to examine the effects of each urban rail transit line on residential location choice behavior.

The rest of this chapter is organized as follows. The next section explains data collection and variable specifications. Then, the descriptive statistics will be described. Finally, discrete choice models, namely multinomial logit (ML), nested logit (NL), rank-ordered logit (ROL) and rank-ordered nested logit (RONL) model will be used to calibrate the residential location choices made by households.

6.3 Data Collection

Bangkok Metropolitan Region and the households where their workplace are located in the CBD of the BMR were chosen as a case context for this paper for several reasons. One, due to the fact, the BMR has among the worst traffic congestion; travel speed by private car head to the inner city is less than 12 kilometer per hours (Office of Transport and Traffic Policy and Planning, OTP). Congestion increases commuting time and costs, which in turn likely draws households to rail-served locations. Two, mainly systems of rail service serves to the inner city where employment locations are largely concentrated physically. Last, the city of Bangkok metropolitan Region has developed a long-range transportation master plan especially urban rail transit, which has impact on a wide range of elements of urban form and transportation development. Understanding that development and corporate into the planning is necessary. Unfortunately, it is characteristics of developing countries including Thailand that do not evaluation and integrate the impact of transportation development as part of the transportation master plan. Therefore, it is necessary that planning and evaluation of transport project in Thailand need to be improved. On top of that, households whose workers work near the CBD may choose residential locations near the rail station because the urban rail transit is likely to be dominant mode to access their workplace in order to reduce the time and costs. The intention in this study specifically is not to consider what would best for the population, but, rather, to consider the sensitivities of the population to a specific set of elements addressed in the plan.

The data base used to carry out this paper was obtained from various sources. Mainly data used for residential location choice decision was obtained from the paper-based questionnaire survey. Fifteen alternatives which are the parts of area in the Bangkok Metropolitan Region were presented to the respondents. Figure 6 - 1 shows an example sheet presenting an alternative.



District	Sub-district	Price range	District	Sub-district	Price range	District	Sub-district	Price range
(1) Watthana	Phra Khanon Nuea	5-10 MB	(2) Chatuchak	Sena Nikhom	3-8 MB	(3) Phra Khanong	Bang Chak	3-8 MB
(4) Saphan Sung	Saphan Sung	3-8 MB	(5) Beung Kum	Khlong Kum	3-8 MB	(6) Thawi Watthana	Sala Thammasop	3-8 MB
(7) Chom Thong	Bang Mot	3-8 MB	(8) Bang Khae	Lak Song	3-8 MB	(9) Lak Si	Thung Song Hong	3-8 MB
(10) Min Buri	Min Buri	1-5 MB	(11) Bang Bon	Bang Bon	1-5 MB	(12) Nonthaburi	Bang Kruai	1-5 MB
(13) Nonthaburi	Tha It	1-5 MB	(14) Nonthaburi	Ban Mai	1-5 MB	(15) Phathum Thani	Amphoe Phathum	1-5 MB

Figure 6 - 1 Sample Choice Experiment

The questionnaire survey was conducted during 8-20 June 2012 on workdays at 10.00 am.-8 pm. at 1) Sathorn and Chong Nonsi areas, 2) Silom area, 3) Ractchadamri area, 4) Phloen Chit and Wireless road area, 5) Sukhumvit area, and 6) Pecthaburi area where there are located in the two major CBD area of Bangkok, namely Silom and Sukhumvit. A stated preference approach was used, where each of a sample of a respondent was asked to imagine moving to a new home location and to indicate preferences among hypothetical alternatives for this new location by ranking (the respondents were asked to rank only 2 from 15 alternatives: first and second preferences), with these alternatives described in terms of attributes related to the options such urban rail transit station, shopping center, expressway network. The respondents were asked to do the questionnaire by interview individually as shown in Figure 6 - 2. The observations of choice behavior thus obtained were then used to estimate model parameters indicating the sensitivities to those attributes.

Figure 6 - 2 Interview Survey for Residential Location Decision

Furthermore, the respondents were asked general questions about: (1) their personal and household information such as household size, household income, car ownership and current home location and (2) travel mode choice by explaining the travel choice consideration from their house to their workplace and the travel time.

6.4 Variable Specifications

The explanatory variables considered in the residential location choice decisions are broadly classified into seven groups together with socio-demographics interactions and summarized in Table 6 - 1, described as below.

Local transportation accessibility variable relate to the urban rail transit and expressway facilities within zones: transit service availability, proximity to the rail transit station and the expressway ramp (as in access ramp). For the transit service availability within zones, the dummy variable is employed. The value is set to 1 if those alternative zones are served by urban rail transit, and set to 0 otherwise. The proximity to the rail transit station and the expressway ramp refer to the straight line distance to the nearest transit station and the expressway access ramp which are computed using the Geographic Information System (GIS) tools. These measures are included because they represent local measures of transit and auto levels of service which can impact the residential choice decisions.

Work and non-work accessibility variable refers to commute time (minute) to the central business district where there are physically concentrated in the inner core of the Bangkok Metropolitan Region: Sukhumvit and Silom Area and distance to shopping center (similar to chapter 4 and 5). Commuting time is computed from the TDMC5 model by making use of JICA STRADA's trip and transit assignment program. For this variable, we measured by using the dummy variable. The value is set to 1 if those alternative zones are located within 45 minute from the CBD, and set to 0 otherwise. The past studies revealed that the commute time to workplace influences on the residential location choice, however, they are unclear as to how long be acceptable.

Table 6 - 1 Variables Description and Data Sources for Residential Location Decision

Variables	Description	Data Source
Local transportation accessibility		
DIST_STA	Distance to nearest station (km)	Calculated using GIS
DIST_GSTA	Distance to nearest station of BTS Skytrain (km)	Calculated using GIS
DIST_BSTA	Distance to nearest station of MRT Blue Line (km)	Calculated using GIS
DIST_ASTA	Distance to nearest station of Airport Rail Link (km)	Calculated using GIS
DIST_PSTA	Distance to nearest station of MRT Purple Line (km)	Calculated using GIS
DIST_RSTA	Distance to nearest station of SRT Red Line (km)	Calculated using GIS
DIST_EXP x NO_CAR	Distance to expressway interacted with car ownership (dummy variable, value is 1 if households without car ownership, 0 otherwise)	Calculated using GIS
DIST_EXP x CAR_OWN	Distance to expressway interacted with car ownership (dummy variable, value is 1 if households own at least one car, 0 otherwise)	Calculated using GIS
Work and non-work accessibility		
COM_TIME45m	Commute time to workplace (dummy variable, value is 1 if each zone of alternative can reach to the CBD within 45 minute, 0 otherwise)	JICA STRADA
DIST_SHOPPING	Distance to shopping center (km)	Calculated using GIS
Housing affordability		
LAND_PRICE	Land price (baht/sq.m)	Treasury Department
Neighborhood amenity		
MED_INC	Median income (baht)	The Transportation Model of Bangkok Metropolitan Region (e-BUM) and Questionnaire survey
EMP_DENS x LOW_INC	Employment density interacted with low income (1/0)	
EMP_DENS x MID_INC	Employment density interacted with middle income households (1/0)	
EMP_DENS x HIGH_INC	Employment density interacted with high income households (1/0)	
SCHOOL_DENS	School density (students per square kilometer)	
Land attribute		
A_INDUSTRIAL	Area of Industrial land use (square kilometer)	Bangkok Metropolitan Administration (BMA)
Household demographic		
LOW_INC	Low income households (dummy variable, value1 if income is less than 20,000 baht per month, 0 otherwise)	Questionnaire survey
MID_INC	Middle income households (dummy variable, value1 if income is 20,000 – 50,000 baht per month, 0 otherwise)	
HIGH_INC	High income households (dummy variable, value1 if income is more than 50,000 baht per month, 0 otherwise)	
TRAN_USER	Household mainly get to work by rail transit (dummy variable, value1 if get to work by rail transit, 0 otherwise)	
HOME_RPASS	Current home location (dummy value 1 if current home location is served by rail transit system, 0 otherwise)	
MEMBER_LESS_3	Household size (dummy variable, value 1 if number of member less than 3, 0 otherwise)	

Housing affordability variable refers to assessed land price (baht/sq.m) in each zone. The government appraised land value was obtained from the assessed land value reports, which were published by The Treasury Department, Thailand. The period time of land price is during the year 2008 and 2011. Typically, assessed value (price) is the value used by local governments to determine the property taxes. This is generally an unrealistic value. Often times too low, but sometimes high; however, it often bears relationship to the real value of property. Although the assessed land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand.

Neighborhood amenity variable includes the density of each zone (e.g. population per square kilometer, employment per square kilometer as well as student per square kilometer). Again, the density of the zones is also obtained from the transportation model of Bangkok Metropolitan Region (e-BUM). This variable is chosen to determine the effect of neighborhood environment on residential choice. For example, households tend to live in the high school density, but lower employment density.

Land attribute means the land composition which refers to industrial land use area (sq.km). In addition, land use composition data was obtained from Department of City Planning and Department of Public Works and Town and Country Planning, Thailand. I would expect the estimated coefficient of this variable to be consistently negative, meaning that households are less likely to live in the areas with a higher share of industrial land use area.

Furthermore, an investigation into the relationship between housing preferences and choice of residential location is associated with the different groups of households. In this paper, household composition, namely, income level, car ownership, travel behavior, current home location, and size of household is an important variable to consider with regard to location decision. Specifically, income level was divided into three groups: low income (less than 20,000 baht or US$670 per month), middle income (20,000 baht – 50,000 baht or US$670 – US$1,670 per month) and high income (more than 50,000 baht or US$1,670 per month). Next, the TRAN_USER variable assigns to capture the behavior of daily trip for work purpose. In addition, this variable indicates by dummy variable: the value set to 1 if households often get to work using rail transit and otherwise set to 0. While, the current home location (HOME_RPASS) also indicates by dummy variable in order to understanding the preferences of households, who presently live near the rail transit network and live far away, in residential location decisions. Finally, the member of household also measures by dummy variable (NUMBER_LESS_3): the value set to 1 if the member is less than three persons per households and otherwise set to 0.

Another important focus of this paper is to examine the variations in sensitivity across the households to attributes of alternatives such as local transportation accessibility, work accessibility, median land value as well as zonal density and land use structure. For example, housing price has a negative effect on location preference; however, this effect decreases as the household income increases (de Palma *et al.*, 2005). In the other word, households with high income earnings are less sensitive to the housing price than those with low income earnings. Thus, we combine the different groups of variables identified in the earlier sections with the household demographics such as income, household structure, as well as the household daily trips.

6.5 Characteristics of Respondents

A random 1,100 households in Bangkok Metropolitan Region was chosen for face-to-face interview. Only 1,060 completed questionnaires were usable for the data analysis. There were 40 unacceptable questionnaires due to several reasons: (1) patterns of responses and (2) responses with little variance. These questionnaires with unsatisfactory responses were discarded. The findings from the questionnaires are broadly classified into six groups: respondent characteristics, current housing situation, travel behavior, influencing factor during housing search process and attitudes and preferences. These findings will be briefly interpreted as below. Additionally, this information is useful for understanding the context of the residential location choice behavior.

6.5.1 Personal and Household Information

In this section, general information of the respondents is described using descriptive statistics. The findings of personal characteristics and household characteristics from questionnaires such as age, marital status, education level, household size, household income, household car ownership, etc. are summarized in Table 6 - 2 and Table 6 - 3 respectively and discussed as below.

Table 6 - 2 Personal Characteristics

Individual characteristics	Male		Female	
	Frequency	Percentage	Frequency	Percentage
Age				
Below 30 years	159	37.15	163	25.79
30-39 years	190	44.39	341	53.96
40-49 years	71	16.59	118	18.67
Above 49 years	8	1.87	10	1.58
Marital status				
Single	274	64.02	243	38.45
Married	153	35.75	387	61.23
Married with children	90	21.03	238	37.66
Married without children	63	14.72	149	23.57
Others	1	0.23	2	0.32
Education level				
< Bachelor degree	49	11.45	45	7.12
Bachelor degree	346	80.84	549	86.87
>Bachelor degree	33	7.71	38	6.01
Occupation				
Self employment	25	5.84	38	6.01
Private employee	370	86.45	529	83.70
Government officer	25	5.84	51	8.07
Part time	8	1.87	14	2.22
Monthly income (baht)				
<10,000	3	0.70	6	0.95
10,001-20,000	96	22.43	168	26.58
20,001-30,000	205	47.90	328	51.90
30,001-50,000	114	26.63	121	19.15
>50,000	10	2.34	9	1.42

Table 6 - 2 presents background characteristics of the 428 men and 632 women interviewed. The age of respondents ranges from 20 to 58, with an average of 33.7 years old. In the table, age ranges were divided into four groups: less than 30 years, 30-39 years, 40-49 years and more than 49 years.
The findings show that the distribution of respondents according to age shows a generally similar pattern for male and female respondents. The proportion of respondents in each age group declines with increasing age for both sexes except the "below 30 years of age" group. More than half of respondents (81.54 percent male and 79.75 percent female) were under 40 years and less than 10 percent of male and female respondents were above 49 years.

In term of marital status, it was identified by single, married, married with and without children and others. Let notice the table, female respondents were much more likely than male respondents to have married (35.75 percents for males and 61.23 percent for females). Among married respondents, 21.03 percent of males and 37.66 percent of females indicated that they have children 15 years old or younger while 14.72 percent of males and 23.57 of females do not have children.

The sample comprised of a high proportion of respondents (88.55 percent males and 92.88 percent females) with university or professional degree. The main reason for the high proportion of university degree holders in the sample was probably due to the characteristics of the urban population. Better employment opportunities available in the CBD do lead to concentration of higher education people. Employment status was as follows: more than 80 percent of male and female respondents were employed in the private sector, but less than 10 percent were self employment, and government officer.

In term of monthly income of respondents, the distribution presents the similar pattern for males and females. In addition, 47.90 percent of males and 51.90 percent of females were in the income category of 20,001-30,000 baht, followed by 22.43 percent of males and 26.58 percent of females are in the income category of 10,001-20,000 baht. Although 88.55 percent of men and 92.88 percent of women were university or professional degree holders, but less than of 30 percent are likely to earn a higher income than 30,000 baht.

Table 6 - 3 presents the households characteristics of respondents: the size of household, the number of worker, car ownership and motorcycle ownership. Then, the findings were classified into three groups of household income: low income, middle income and high income class.

In term of household income, the sample comprised of a high proportion of respondents (approximately 60 percent) earns a higher income than 50,000 baht per month which is much higher than the per capita (about 34,000 baht per month in 2010). This was followed by 34.81 and 2.93 percent of respondents were classified in middle income and low income group, respectively.

Among respondents, the average number of members per households is 3.45. Specifically, a household is composed of 2.64, 2.93, 3.78 persons in low income, middle income and high income class, respectively. In the table, the high proportion of low income respondents indicated that their household composed of one person (45.16 percent), while it found only 13.01 percent in middle income respondents. Next, approximately 23 percent of middle income and 30 percent of high income respondents are from households with 3-4 persons. These imply that larger households normally require a greater level of income to maintain the same material standard of living as smaller households.

On the other hand, the average number of workers per households is 2.44. In the table, the distribution of household worker according to household income level, the proportion of household workers rises with increasing income level. Specifically, 80.65 percent of low income respondents indicated their household had only one worker, while it found only 17.07 percent and 0.46 percent in middle income and high income respondents had one worker per household. In contrast, more than 45 percent of middle income and high income respondents indicated they had two workers per household.

Table 6 - 3 Household Characteristics

Household characteristics	Total	Low income	Middle income	High income
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Household income (baht)				
0-20,000	31 (2.93%)	-	-	-
20,001-50,000	369 (34.81%)	-	-	-
>50,000	660 (62.26%)	-	-	-
Household member				
1 person	62 (5.85%)	14 (45.16%)	48 (13.01%)	-
2 persons	207 (19.53%)	2 (6.45%)	110 (29.80%)	95 (14.39%)
3 persons	289 (27.26%)	6 (19.35%)	85 (23.04%)	198 (30.00%)
4 persons	295 (27.83%)	3 (9.69%)	85 (23.04%)	207 (31.36%)
>4 persons	207 (19.53%)	6 (19.35%)	41 (11.11%)	160 (24.24%)
Household worker				
1 person	91 (8.58%)	25 (80.65%)	63 (17.07%)	3 (0.46%)
2 persons	567 (53.49%)	5 (16.13%)	235 (63.69%)	327 (49.55%)
3 persons	238 (22.45%)	1 (3.23%)	52 (14.09%)	185 (28.03%)
>3 persons	164 (15.48%)	-	19 (5.15%)	145 (21.97%)
Household car				
None	292 (27.55%)	23 (74.19%)	185 (50.14%)	84 (12.73%)
1 car	570 (53.77%)	6 (19.35%)	178 (48.24%)	386 (58.49%)
2 cars	148 (13.96%)	2 (6.46%)	5 (1.36%)	141 (21.36%)
3 cars	37 (3.49%)	-	1 (0.27%)	36 (5.45%)
>3 cars	13 (1.23%)	-	-	13 (1.97%)
Household motorcycle				
None	645 (60.85%)	12 (38.71%)	243 (65.85%)	390 (59.09%)
1 car	358 (33.77%)	12 (38.71%)	99 (26.83%)	247 (37.42%)
2 cars	52 (4.90%)	6 (19.35%)	24 (6.50%)	22 (3.33%)
3 cars	5 (0.47%)	1 (3.23%)	3 (0.81%)	1 (0.15%)

For the household vehicles, the statistics shows that more than half of all respondents have access to at least one car per household. However, car availability is associated with the level of income. Approximately 75 percent of the low income respondents do not have access to a car compared to around 50.14 percent of households and 12.73 percent of households in middle and high income group, respectively. In contrast, the higher a household' income, the higher likelihood it will have access to at least one car. Indeed, those households in middle and high income group are also more likely to have access to a larger number of cars, with more than 20 percent of them having access to two or more cars. On the other hand, only 6.46 percent of the low income households have access to two or more cars. Furthermore, it cannot found low income households had access to two or more cars and middle income households had more than three cars.

As expected, at least half of the respondents (approximately 60 percent) do not have access to a motorcycle. One-third of the respondents or 33.77 percent own motorcycles at least one car. Furthermore, a much lower proportion (approximately 5 percent) of the respondents has motorcycles available for use. Finally, from the descriptive statistics, it implies that the respondents with a car are less likely to own a motorcycle, as opposed to the respondents with no car

6.5.2 Housing Type and Home Location

This section provides the basically housing information of the respondents: types of current housing residence status, home location, home served by rail transit or not and travel time gets to work according to the level of income.

In Thailand, there are five major types of housing, i.e., detached houses, semi-detached houses, townhouses, row houses and condominiums/apartments/flats. Among housing type, detached houses and townhouses are more popular than other types. The semi-detached houses are quite small in numbers. Recently, there has been a huge demand of condominiums/apartments in Bangkok, particularly along Bangkok's transit system, the MRT Blue Line and the BTS skytrain. The difference between condominium and apartment according to the local norm is those sales are called condominium and those for rent are called apartment. However, the appearance both condominium and apartment is quite the same. Besides, the row houses sometimes have a dual residential and commercial function.

Among housing types, the sample comprised of the high proportion of the respondents (approximately 40 percent) tends to live in townhouses, followed by 23.58 percent in detached houses and 21.14 percent in percent in condominiums and apartments as presented in Table 6 - 4. These statistics also vary depending on the level of income. Low income households show a greater share of their living (48.39 percent) in condominium and apartment, in contrast, 37.40 percent of middle income and 10.76 percent of high income households. More than 30 percent of the middle income households also live in townhouses, 17.34 percent in detached houses and followed by 11.38 percent in row houses. In term of detached houses, the high proportion of detached house ownership (approximately 27 percent) was found in the high income households.

Next, the residence status was divided into three categories: homeowner, resident and tenant. It found that 47.83 percent of all respondents were resident. This was followed by 37.45 percent were homeowner and 20 percent were tenant. The residence status also varies depending on the level of income. The table shows that 64.52 percent of low income households were tenant but only 9.68 percent was homeowner. On the other hand, 27.10 percent of middle income and high income household indicated that they were homeowner and 34.96 percent and 56.06 percent were resident.

In term of home location, it can be divided into three categories: inner city, urban fringe and suburban and vicinities. Approximately 42.45 percent of the respondents live in the urban fringe, followed by 37.45 percent and 20.10 percent in the inner city and suburban and vicinities, respectively. Furthermore, the distribution of living in each area according to income level was generally the same pattern. Nearly 80 percent of them lived in the inner city and urban fringe. Furthermore, home location was also classified into two groups: home location served by rail transit or not. More than half of the respondents (85 percent) have a current home location without rail transit system served. This because only three rail transit system is now operating and the current coverage area is limited.

Finally, time use to workplace is divided into four levels: less than 30 minutes, 30-60 minutes, 61-90 minutes and more than 90 minutes. In term of time use, the high proportion of the respondents (41.70 percent) spends 30-60 minutes traveling to and from workplace, followed by 36.98 percent spends 61-90 minutes. Furthermore, the differences between the first and second highest of the proportion is slightly small.

Table 6 - 4 Housing Information by Household Income

Housing information	Total	Low income	Middle income	High income
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Housing type				
Detached	250 (23.58%)	5 (16.12%)	64 (17.34%)	181 (27.42%)
Semi-Detached	29 (2.74%)	-	5 (1.36%)	24 (3.64%)
Townhouse	425 (40.09%)	2 (6.45%)	120 (32.52%)	303 (45.91%)
Row house	132 (12.45%)	9 (29.04%)	42 (11.38%)	81 (12.27%)
Condominium/Apartment	224 (21.14%)	15 (48.39%)	138 (37.40%)	71 (10.76%)
Residence status				
Homeowner	341 (32.17%)	3 (9.68%)	100 (27.10%)	238 (36.06%)
Resident	507 (47.83%)	8 (25.81%)	129 (34.96%)	370 (56.06%)
Tenant	212 (20.00%)	20 (64.52%)	140 (37.94%)	52 (7.88%)
Home location				
Inner city	397 (37.45%)	14 (45.16%)	168 (45.53%)	215 (32.58%)
Urban fringe	450 (42.45%)	11 (35.48%)	142 (38.48%)	297 (45.00%)
Suburban and vicinities	213 (20.10%)	6 (19.35%)	59 (15.99%)	148 (22.42%)
Home served by rail transit system				
Served by rail transit system	159 (15.00%)	5 (16.13%)	77 (20.87%)	77 (11.67%)
Non-served by rail transit system	901 (85.00%)	26 (83.87%)	292 (79.13%)	583 (88.33%)
Time use to workplace				
<30 minutes	173 (16.32%)	7 (22.58%)	72 (19.51%)	94 (14.24%)
30-60 minutes	442 (41.70%)	15 (48.39%)	158 (42.82%)	269 (40.76%)
61-90 minutes	392 (36.98%)	7 (22.58%)	122 (33.06%)	263 (39.85%)
>90 minutes	53 (5.00%)	2 (6.45%)	17 (4.61%)	34 (5.15%)

6.5.3 Travel Information

This section provides present travel mode choice of the respondents among personal and household characteristics, and housing information. The modal shares of traveling to work are expressed in Table 6 - 5 and Table 6 - 6. From the obtained data, there are three popular modes used in work daily trips: private mode (i.e., private car and motorcycle), public mode (in this study exclude rail transit mode: BTS Skytrain, MRT Blue Line and Airport Rail Link) and rail transit mode.

Table 6 - 5 Mode Choices among Respondent Characteristics

Respondent characteristics	Private mode	Public mode (exclude rail transit mode)	Rail transit mode
	Frequency (%)	Frequency (%)	Frequency (%)
Age			
Below 30 years	106 (32.92%)	107 (33.23%)	109 (33.85%)
30-39 years	142 (26.74%)	140 (26.37%)	142 (26.74%)
40-49 years	119 (62.96%)	42 (22.22%)	27 (14.29%)
Above 49 years	10 (55.56%)	3 (16.67%)	5 (27.77%)
Marital status			
Single	199 (38.49%)	148 (28.63%)	168 (32.50%)
Married	280 (51.85%)	144 (26.67%)	115 (21.30%)
Married with children	(182) (33.70%)	(84) (15.56%)	(62) (11.48%)
Married without children	(98) (18.15%)	(60) (11.13%)	(53) (9.82%)
Household income level			
Low income level	6 (19.35%)	13 (41.94%)	11 (35.48%)
Middle income level	114 (30.89%)	138 (37.40%)	116 (31.44%)
High income level	362 (54.85%)	141 (21.36%)	156 (23.60%)
Household car			
None	52 (17.81%)	130 (44.52%)	108 (36.99%)
1 car	293 (51.40%)	141 (24.74%)	136 (23.86%)
2 cars	100 (67.57%)	18 (12.16%)	30 (20.27%)
>2 cars	37 (74.00%)	3 (6.00%)	9 (20.00%)

The modal shares among respondent characteristics are summarized in Table 6 - 5. The proportion of private mode inclines as increasing age of the respondents. In addition, private mode is the most preferable for respondents who were over 40 years old (more than 50 percent), in contrast, other modes are less likely to use. However, the distribution of respondents according to mode choice shows a generally similar pattern for age range less than 30 years and 30-39 years.

Also, private mode was the most famous mode for the married couples especially married couples with children. But the statistics show nearly proportion of the modal shares for the single households. Furthermore, we classified the respondents into three main group based on household income level. Definitely, the sample comprised of the high proportion of private mode uses were found in the middle and high income household (approximately 30.89 percent and 54.85 percent, respectively).

On the other hand, public transport mode has the highest shares for the low income households while they owned the lowest shares for the high income households. In term of the household car, the higher a household' car ownership, the higher likelihood it will get to work by private mode.

The modal shares among housing information are summarized in Table 6 - 6. The respondents who live in urban fringe and suburban and vicinities prefer to choose the private mode compared to those live in the inner city. This might be due to less frequent or direct public transport services that are available in urban fringe and suburban and vicinities.

In term of home location served by rail transit system, the results reveal that 67.30 percent of the respondents who live near rail transit service get to work by transit while only 23.27 percent use a private mode. Around 50 percent of the respondents live in the districts without rail transit service availability are more likely to use private mode than other modes.

Among average time use, it found that 59.54 percent of the respondents spend less than 30 minute travels by rail transit mode, followed by 24.28 percent use private mode. Less than 20 percent of the respondents were able to spend less than 30 minutes get to work by public transport mode, but 45.28 percent spend amount of time on the public mode.

Table 6 - 6 Mode Choices among Housing Information

Housing information	Private mode	Public mode (exclude rail transit mode)	Rail transit mode
	Frequency (%)	Frequency (%)	Frequency (%)
Home location			
Inner city	134 (33.75%)	112 (28.21%)	149 (37.53%)
Urban fringe	228 (50.67%)	112 (24.89%)	109 (24.22%)
Suburban and vicinities	120 (56.34%)	68 (31.92%)	25 (11.74%)
Home served by rail transit system			
Served by rail transit system	37 (23.27%)	13 (8.18%)	107 (67.30%)
Non-served by rail transit system	445 (49.39%)	279 (30.97%)	176 (19.53%)
Time use to workplace			
<30 minutes	42 (24.28%)	26 (15.03%)	103 (59.54%)
30-60 minutes	191 (43.21%)	123 (27.83%)	127 (28.73%)
61-90 minutes	220 (56.12%)	122 (31.12%)	50 (12.76%)
>90 minutes	29 (54.72%)	56 (45.28%)	-

6.6 Housing Amenities versus Location Attributes

6.6.1 Housing Priorities

Finding and viewing houses during the home buying process can seem complicated. There are so many things to consider before making decision, thus, it is important to decide what is most wanted. However, as previously discussed in Chapter 2, it points to the attributes and characteristics that are most certain important which can be divided into two main groups: housing amenities (e.g. rent or price, housing type, housing size, number of rooms) and others related to the locational and neighborhood attributes (e.g. accessibility to schools, commute time, crime rate, density) where it is located. Therefore, the respondents were asked to rank five factors from the most to least that influencing their residency selection. Figure 6 - 3 shows the percentage of respondents ranking the housing attributes priority.

Housing attributes priority was divided into five main categories: housing amenity, activity accessibility, transportation accessibility, community and security and social network (Figure 6 - 3). Housing amenity includes housing price/rent, lot size/usable space, and front/back yard. Then, activity accessibility represents the closeness to work location, shopping mall, recreation, open space and so on. Transportation accessibility refers to the proximity to the rail transit station, main road, expressway access and bus stop. Next, community and security involves a secure environment such as road accident, crime rate, pollution and neighbors. Finally, social contact is facilitated by family and friend, i.e., moving closer to family members/friends.

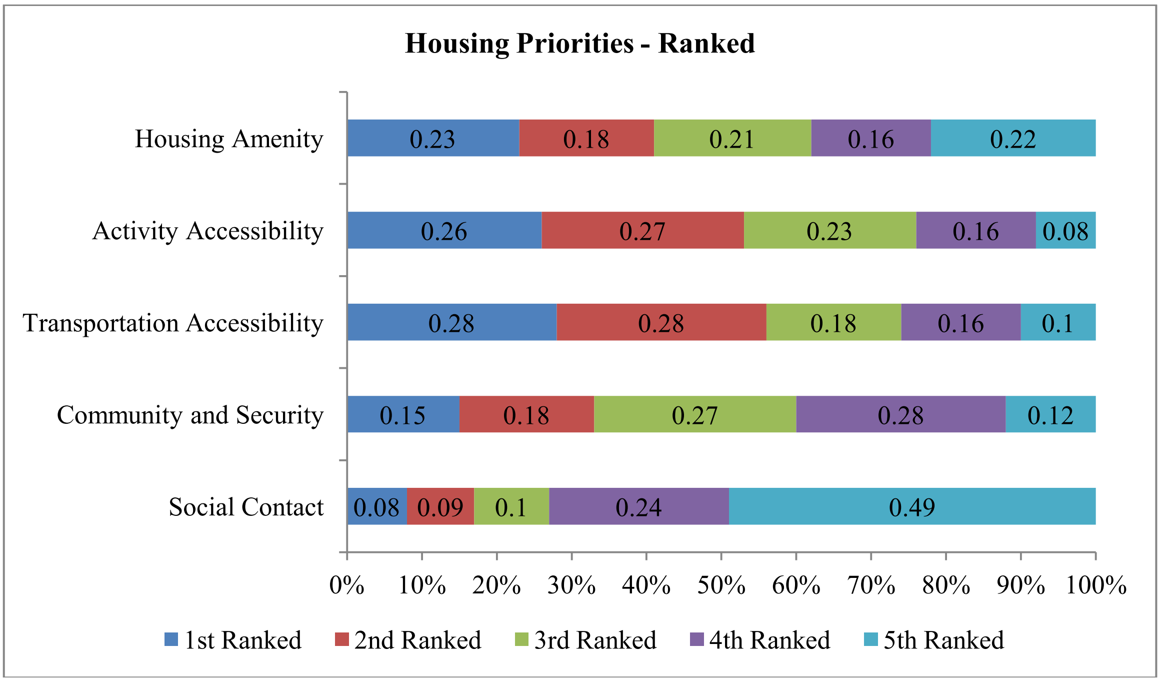


Figure 6 - 3 Housing Priorities

From the Figure 6 - 3, the results show that 23 percent of respondents ranked housing amenity first, very close followed by 18 percent and 21 percent ranked it second and third, respectively. Next, the distribution of the respondents reveals a generally similar pattern for activity accessibility and transportation accessibility, i.e., both of them were ranked as the higher priority while community and security seem neutral. Furthermore, it can be seen that only 8 percent of the respondents ranked the social contact first while nearly 50 percent of the respondents ranked it as the least important. Obviously, it is interesting to note that transportation accessibility is the most important attribute to the respondents, indicated by 28 percent of respondents ranked it first among housing priority attributes, closely followed by activity accessibility (26 percent) and housing amenity (23 percent).

This is because of Bangkok's congestion, inadequate and poor public transport service as explained earlier. Locations with the greater accessibility to transportation and activity offer many benefits such as reduce cost and time and make them comfort and convenient.

Table 6 - 7 Housing Priorities: Most Influential Factors (Factor Ranked First)

Housing priorities	Low income	Middle income	High income
	Frequency (%)	Frequency (%)	Frequency (%)
Housing amenity	14 (45.16%)	85 (23.04%)	142 (21.52%)
Activity accessibility	5 (16.13%)	82 (22.22%)	191 (28.94%)
Transportation accessibility	5 (16.13%)	114 (30.89%)	177 (26.82%)
Community and security	3 (9.68%)	54 (14.63%)	107 (16.21%)
Social contact	4 (12.90%)	34 (9.21%)	43 (6.52%)

Table 6 - 7 presents the most influential factors (factor ranked first) for housing priorities among household income. It found that housing amenity was the top rank attribute that was the most influential in attracting low income households during the home buying process (approximately 45 percent). This was followed by activity and transportation accessibility, respectively. However, middle income households ranked transportation accessibility (30.89 percent) and high income households ranked activity accessibility (28.94 percent) as the most influential attribute.

6.6.2 Local Transportation Accessibility

As discussed in the section 6.6.2, the results presented that the transportation accessibility is the most important factor in the process of searching for a new home/locations. In this section, among transportation accessibility, namely rail transit station, main road, expressway access and bus stop were also ranked from the most to least important. Figure 6 - 4 listed those attributes, along with the percentage distribution of each rank.

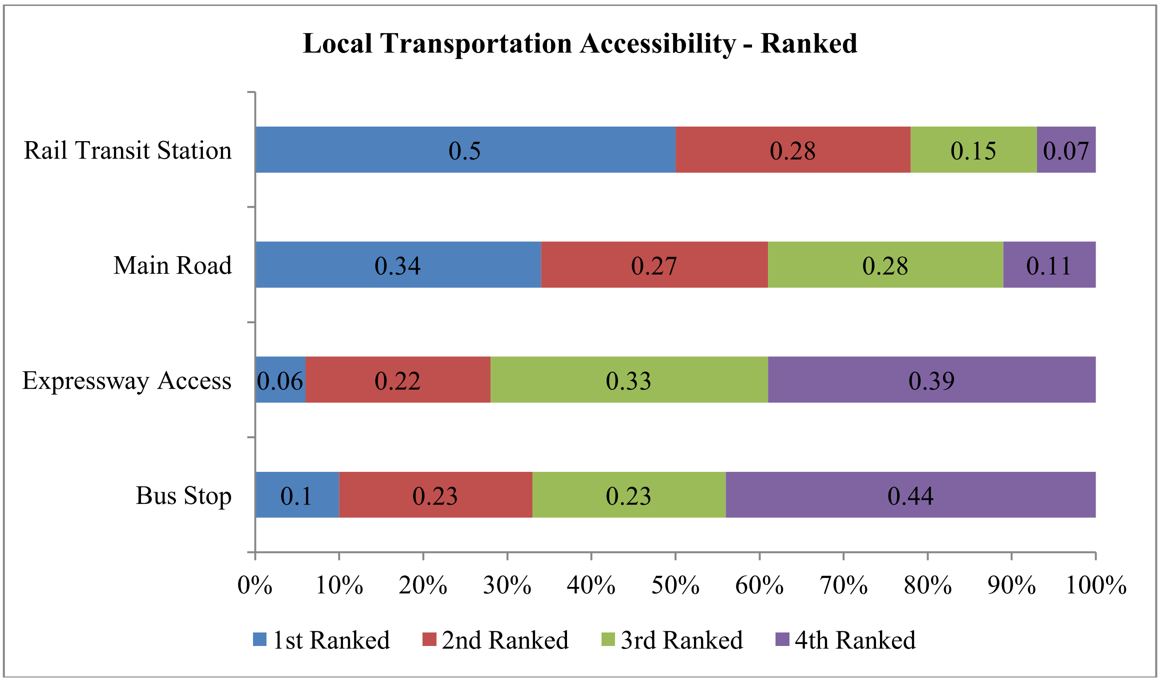


Figure 6 - 4 Importance of Local Transportation Accessibility

From the Figure 6 - 4, fifty percent of respondents ranked “closeness to the rail transit station” as the most important factor influencing their residency selection among local transportation accessibility. Specifically, the results show that 50 percent of respondents ranked closeness to rail transit station first, followed by 28 percent and 15 percent ranked it second and third, respectively. Then, thirty four percent of respondents ranked proximity to main road first, slightly followed by 27 percent and 28 percent ranked it second and third, respectively. In contrast, closeness to expressway access and distance to bus stop were ranked as the most important attributes around 10 percent of respondents.

Table 6 - 8 Local Transportation Accessibility: Most Influential Factors (Factor Ranked First)

Local transportation accessibility	Private mode	Public mode (exclude rail transit mode)	Rail transit mode
	Frequency (%)	Frequency (%)	Frequency (%)
Rail transit station	217 (45.02%)	132 (45.21%)	179 (63.25%)
Main road	187 (38.80%)	108 (36.99%)	67 (23.67%)
Expressway access	49 (10.17%)	6 (2.05%)	9 (3.18%)
Bus stop	29 (6.01%)	46 (15.75%)	28 (9.89%)

Table 6 - 8 presents the most influential factors (factor ranked first) for local transportation accessibility among mode choices. This result clears that the closeness to rail transit station is the most important attributes for all users (i.e. private modem, public mode and rail transit mode) when they look for a new living place. The proximity to rail transit station was ranked as the most influential attribute for all respondents. This was followed by distance to main road. Among private mode users, 10.17 percent of them indicated the closeness to expressway access as the third most important while it found only 2.05 percent of public mode users and 3.18 percent of rail transit mode users selected this attributes. Among public mode and rail transit mode users, 25.64 percent of them selected proximity to bus stop as the third most important.

6.7 Residential Location Choice Model Specification

6.7.1 Multinomial Logit Model

For a given individual n = 1, 2,.., N where N is the number of individual decision-makers, and an alternative j = 1, 2,.., J where J is the number of alternatives. The utilities for individual n = 1, 2,.., N are given by $U_{nj} = U_{n1},\ldots,U_{nJ}$. Traditionally, each of individual n is asked to choose the most preferred alternative out of the complete set of J alternatives. Let y_{nj} =1 indicates the observed choice that person n prefers alternative j most. Thus, the ML model can be written as follows.

$$y_{nj} = \begin{cases} 1 & if \quad U_{nj} > U_{ni} \text{ , for } j = 1,\ldots,J \\ 0 & \quad\quad \text{otherwise} \end{cases} \tag{6.1}$$

$$U_{nj} = \beta X_{nj} + \varepsilon_{nj} = V_{nj} + \varepsilon_{nj} \tag{6.2}$$

where X_{nj} is a vector of observed explanatory variables describing individual n and alternative j.

β is the vector of coefficients to be estimated and ε_{nj} is a random unobserved component of utility, assumed to be independent and identically distributed (iid)[4]. The term $\boldsymbol{\beta}X_{nj}$ in equation (6.2) is known as the deterministic or systematic component of the utility function, denoted as V. Based on above structure, the probability that individual n chose alternative j is given by:

$$P_{nj} = \frac{\exp\left(V_{nj}\right)}{\sum_{j=1}^{J}\exp\left(V_{nJ}\right)} \tag{6.3}$$

6.7.2 Nested Logit Model

The multinomial logit model (ML) has been widely used due to its simple formulation form, ease of estimation and interpretation. However, the ML model is derived from the assumptions about the characteristics of choice probabilities, namely the independence of irrelevant alternative (IIA) which implies proportional substitution across alternatives. Generalized extreme value (GEV) models constitute a large class of models that exhibit a variety of substitution patterns. The most widely used member of the GEV family is called nested logit model. The mathematical formulation of this model follows the utility maximizing NL model developed by McFadden (1978).

A conceptual two-tiered nested logit model of residential location choice is shown in Figure 6 - 5. This nested model is hierarchical and sequential, treating the influences of proximity to transit station on location/district choice directly. In this tree diagram, residential location is expressed in binary terms: either one resides in districts with a rail station or not. The bottom level of the tree, location choice, is represented as a part of area in Bangkok Metropolitan Region or generally called districts. Then, the 15 alternatives were classified, into two groups: districts with rail transit station and districts without rail transit station.

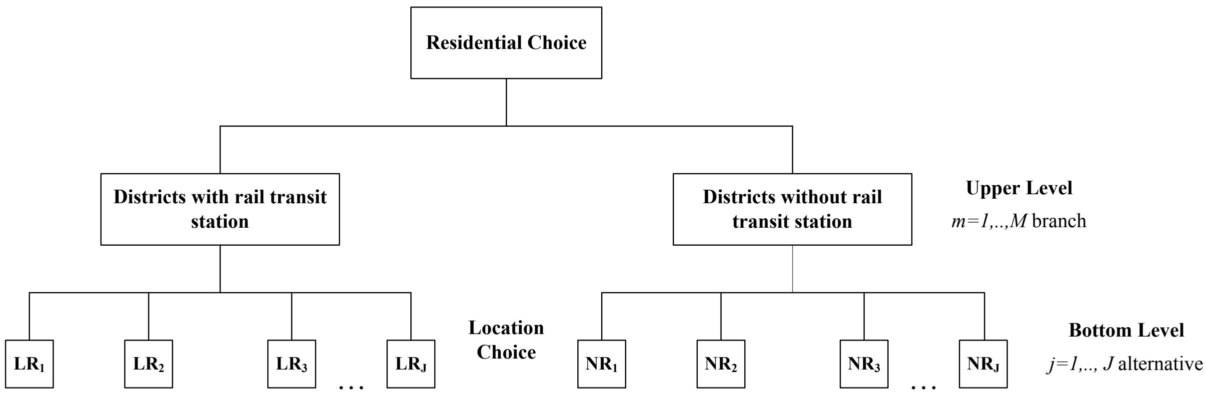


Figure 6 - 5 Two-Tiered Nested Structure of Residential Location Choice

From the Figure 6 - 5, a set of alternative in the bottom level was indexed by j = 1, 2,.., J and the nest in the upper level by m=1,2,.., M. Let y_{nj} is an indicator variable for the alternative j in the upper level m chosen by individual n. The nested logit probability can be written as follows:

$$P_{nj} = P_{nj|m} \times P_{nm} \tag{6.4}$$

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[4] An iid assumption on the Gumbel error term imposes the independence of irrelevant alternatives (IIA) property (Train, 2002)

where $P_{nj|m}$ is the conditional probability of choosing j given that an alternative in upper nest m is chosen and P_{nm} is the marginal probability of choosing an alternative in upper nest m .

The bottom level conditional choice probability takes the form of the standard multinomial logit model (ML) formula and so can be written as follow:

$$P_{nj|m} = \frac{\exp\left(V_{nj|m} / \lambda_{\mathrm{m}}\right)}{\sum_{j \in M} \exp\left(V_{nJ|m} / \lambda_{\mathrm{m}}\right)} \tag{6.5}$$

where $V_{nj|m}$ is the component of utility for individual n choosing alternative j given location choice m, while λ is called the dissimilarity parameter, reflecting different correlation among unobserved factors within each nest. The range of this dissimilarity parameter should between 0 and 1 for all nests. A high λ means greater independence and less correlation. Therefore, a value of $\lambda_{\mathrm{m}} = 1$ means complete independence in nest m. Obviously, if $\lambda_{\mathrm{m}} = 1$ for all nests, then the GEV distribution simply becomes the produce of independent extreme value terms, i.e., the nested logit reduces to the standard logit model.

The marginal choice probability of choosing nest m has the form:

$$P_{nm} = \frac{\exp\left(V_{nm} + \lambda_{\mathrm{m}} \mathrm{I}_{\mathrm{m}}\right)}{\sum_{m=1}^{M} \exp\left(V_{nM} + \lambda_{\mathrm{m}} \mathrm{I}_{\mathrm{m}}\right)} \tag{6.6}$$

where V_{nm} is the measurable component of utility for individual n choosing alternative in upper nest m. The inclusive value for the m nest (denoted this value by I_{m}) corresponds to the expected value of the utility that individual n obtained by consuming an alternative j in upper nest m is defined as:

$$\mathrm{I}_{\mathrm{m}} = \ln \sum_{j \in m} \exp(V_{nJ|m} / \lambda_{\mathrm{m}}) \tag{6.7}$$

6.7.3 Rank-Ordered Logit Model

The rank-ordered logit model (ROL), which is an extension of the multinomial logit model, was introduced in the literature by Beggs *et al.* (1981). Empirical applications describing preferences using the ROL model can be found in several fields such as school choice (Drewes and Michael, 2006; Mark *et al.*, 2004) and transportation studies (Calfee *et al.*, 2001; Kockelman *et al.*, 2009; Srinivasan *et al.*, 2006), but less intention in residential location choice studies in recently.

Traditionally, the application of discrete choice model for a choice experiment measures the importance of the features of a good or service by asking each individual to choose his/her preferred alternative from a number of choice sets while a rank-ordered experiment is achieved by asking the respondents to rank a number of alternatives within the choice sets. In this way, the respondents can be asked to state which alternative they would choose, then, after they made this choice, they can be asked to which the remaining alternatives they would choose, continuing through all the alternatives. This process can reflect the better view on the preferences of a household. The model specification (Fok *et al.*, 2010; Kockelman *et al.*, 2009; Train, 2002) will be describe as below.

As in the case of multinomial logit model, the rank-ordered logit can be motivated by a random utility model (RUM). Using RUM theory, the utility of an alternative j for person n can be written as equation (6.2). In the situation of the ROL model, the first rank alternative is imagined as the most preferred alternative with the highest utility in the standard multinomial logit model. The second rank is viewed as the preferred alternative from the entire choice set except the ones with a better ranking (a choice set without the first rank alternative). From this point of view, the ranking is deterministic. Then, the utilities for ranking can be expressed as:

$$U_{nj_{n1}} > U_{nj_{n2}} > \ldots \qquad \ldots \tag{6.8}$$

where $j_{nr} = \{ j_{n1},\ j_{n2},\ldots,\ j_{nJ} \}$ denotes alternative *j* that received rank *r* by individual *n*. For example, $U_{nj_{n1}}$ now denotes the utility of the first rank that individual *n* gives to alternative *j* and $U_{nj_{n2}}$ denotes the utility of the second rank that individual *n* gives to alternative *j*.

According to the iid nature of the error term, the probability that a given ranking of alternatives will be observed equals the probability of choosing the first ranked alternative from the set of *J* alternatives, times the probability of choosing the second ranked alternative from the remaining *J*-1, and so on.

Under the above assumption, the probability of the ROL can be written as follows:

$$\Pr[U_{nj_{n1}} > U_{nj_{n2}} > \ldots \qquad \ldots \qquad \prod_{j=1}^{J-1} \frac{\exp\left(V_{nj_{nr}}\right)}{\sum_{h=j}^{J} \exp\left(V_{nJ_{nh}}\right)} \tag{6.9}$$

6.7.4 Rank-Ordered Nested Logit Model

An alternative to the conventional logit model is the rank-ordered nested logit model. The RONL model partially relaxes the IIA assumption in the ROL model, which is the same as in the ML model; using generalized extreme value (GEV) models constitute a large class of models that exhibit a variety of substitution patterns. The most widely used member of the GEV family is called nested logit model (NL). In addition, the mathematical formulation of this model is developed a nested logit (NL) framework for rank-ordered alternatives (Jafari, 2010) following the utility maximizing NL model developed by McFadden (1978).
Following the Figure 6 - 5, the utility for ranking can be expressed as equation (6.8). The probability of rank-ordered nested logit can be expressed as the product of two simple rank-ordered logits.

$$P_{nj_{nr}} = P_{nj_{nr}|m_r} \times P_{nm_r} \tag{6.10}$$

where $P_{nj_{nr}|m_{nr}}$ is the conditional probability that individual *n* ranks alternative *j* given in the upper nest *m* and P_{nm_r} is the marginal probability of ranking alternative in upper nest *m*.

Now, let *r* = 1 denotes the rank that individual *n* gives alternative *j* as the first rank. The probability of the first rank can be expressed as follow:

$$P_{nj_{n1}} = P_{nj_{n1}|m_1} \times P_{nm_1} \tag{6.11}$$

The conditional and marginal probabilities for the first ranked alternative can be written as follows:

$$P_{nj_{n1}|m_1} = \frac{\exp\left(V_{nj_{n1}|m_1} / \lambda_{\mathrm{m}_1}\right)}{\sum_{j \in m_1}^{J} \exp\left(V_{nJ|m_1} / \lambda_{\mathrm{m}_1}\right)} \tag{6.12}$$

$$P_{nm_1} = \frac{\exp\left(V_{nm_1} + \lambda_{\mathrm{m}_1}\mathrm{I}_{\mathrm{m}_1}\right)}{\sum_{m=1}^{M}\exp\left(V_{nm} + \lambda_{\mathrm{m}}\mathrm{I}_{\mathrm{m}}\right)} \tag{6.13}$$

where $V_{nj_{n1}|m_1}$ is the deterministic component of utility for individual *n* ranking alternative *j* given in the upper nest *m* as the first rank and V_{nm_1} is the measurable component of utility for individual *n* ranking the upper nest *m*, while λ is called the dissimilarity parameter, reflecting different correlation among unobserved factors within each nest. The range of this dissimilarity parameter should between 0 and 1 for all nests. A high λ means greater independence and less correlation. Therefore, a value of $\lambda_{\mathrm{m}} = 1$ means complete independence in the upper level *m*, obviously, if $\lambda_{\mathrm{m}} = 1$ for all nests, then the GEV distribution simply becomes the produce of independent extreme value terms, i.e., the rank-ordered nested logit reduces to the standard rank-ordered logit model.

The inclusive value for the upper nest *m* (denoted this value by I_{m}) corresponds to the expected value of the utility that individual *n* obtains by consuming an alternative *j* in the upper nest *m* is defined as:

$$\mathrm{I}_{\mathrm{m}_1} = \ln \sum\nolimits_{j \in m_1} \exp(V_{nJ|m_1} / \lambda_{\mathrm{m}_1}) \tag{6.14}$$

Next, let *r* = 2 if individual *n* ranks alternative *j* from the remaining *J*-1 in the upper nest *m* (after remove the first rank alternative) as the second rank. The probability of the second rank can be written as follow:

$$P_{nj_{n2}} = P_{nj_{n2}|m_2} \times P_{nm_2} \tag{6.15}$$

If the second rank alternative is not in the same nest as the first rank, the bottom level conditional choice probability can be written similar to the equation (6.12). Then, the marginal choice probability of ranking upper nest *m* (that containing the second rank alternative *j*) has the form the same as equation (6.13) and the inclusive value can be written as equation (6.14).

If the second rank alternative is in the same nest as the first rank, the bottom level conditional choice probability after remove the first rank alternative can be written as follow:

$$P_{nj_{n2}|m_2} = \frac{\exp\left(V_{nj_{n2}|m_2} / \lambda_{\mathrm{m}_2}\right)}{\sum_{j \in m_2, j \neq j_{n1}} \exp\left(V_{nJ|m_2} / \lambda_{\mathrm{m}_2}\right)} \tag{6.16}$$

The marginal choice probability of ranking upper nest *m* (that containing the first and the second ranked alternative in the same nest) has the form:

$$P_{nm_2} = \frac{\exp\left(V_{nm_2} + \lambda_{\mathrm{m}_2}\mathrm{I}_{\mathrm{m}_2}\right)}{\sum_{m=1}^{M-1}\exp\left(V_{nm} + \lambda_{\mathrm{m}}\mathrm{I}_{\mathrm{m}}\right)} \tag{6.17}$$

The inclusive value for the upper nest *m* has the form:

$$\mathrm{I}_{\mathrm{m}_2} = \ln \sum_{j \in m_2, j \neq j_{n1}} \exp(V_{nJ|m_2} / \lambda_{\mathrm{m}_2}) \tag{6.18}$$

Also, to obtain the other choice probabilities with lower ranking, they can be treated in a similar way. Finally, the probability that a given ranking of alternatives will be observed equals the probability of choosing the first ranked alternative from the set of *J* alternatives, times the probability of choosing the second ranked alternative from the remaining *J*-1, and so on.

$$\Pr[U_{nj_{n1}} > U_{nj_{n2}} > \dots \qquad \dots \qquad P_{nj_{n1}} \times P_{nj_{n2}} \times \dots \times P_{nj_{nr}} \tag{6.19}$$

6.8 Influencing Factors in Residential Location Decision

This section examines how the role of urban rail transit affected in determining residential location decisions. Traditional discrete choice model, i.e., multinomial logit (ML) and nested logit (NL) model together with discrete choice models for ranking of alternatives, namely rank-ordered (ROL) and rank-ordered nested logit (RONL) model were applied to estimate. To capture the effects of urban rail transit in determining residential location decisions, each model type was estimated for two measures of accessibility to urban rail transit stations (access to closet station and access to closet station for each line) for three mode choice users (private, public and rail transit mode) and for three income groups (low, middle and high income).

Estimation results are presented in Table 6 - 9 to Table 6 - 14. Full information maximum likelihood estimation was used in deriving estimates. Variables were included in models' utility expressions on the basis of econometric theory and statistical fits. Then, the models were compared to each other in order to determine which among them exhibited the best fit.

6.8.1 Residential Location Choice Model by Access to Closet Station

After extensive experimentations with different specifications, the model results were chosen based on the theoretical and statistical significance of the estimated parameters. Table 6 - 9 to Table 6 - 14 present multinomial logit (ML), nested logit (NL), rank-ordered logit (ROL) and rank-ordered nested logit (RONL) results for measure of accessibility to closet station as well as measure of accessibility to closet station incorporating with travel mode choices and household income. In general, the models give the same sign of parameter estimated, i.e., there are similar behavioral interpretations and each of which is as expected.

In addition, from the Table 6 - 9 to Table 6 - 14, the equations of residential location choice model can be written as below. For residential location choice model by access to closest station;

ML model: – 0.2980xDIST_STA + 0.53395xTRAN_AVAxTRAN_USER + 0.7988xDIST_EXPxNO_CAR + 0.7520xDIST_EXPxCAR_OWN + 0.3759xCOM_TIME45m – 1.6714xLAND_PRICE + 1.8870xMED_INC + 1.5505xEMP_DENSxLOW_INC + 0.9092xEMP_DENSxMID_INC + 0.6510xEMP_DENSxHIGH_INC + 2.1469xSCHOOL_DENS – 0.1175xINDUSTRIAL

NL model: – 0.2156xDIST_STA + 0.0852xTRAN_AVAxTRAN_USER + 0.2369xDIST_EXPxNO_CAR + 0.2045xDIST_EXPxCAR_OWN + 0.0927xCOM_TIME45m – 0.3894xLAND_PRICE + 0.5971xMED_INC + 0.4257EMP_DENSxLOW_INC + 0.2372xEMP_DENSxMID_INC + 0.1672xEMP_DENSxHIGH_INC + 0.5775xSCHOOL_DENS – 0.0319xINDUSTRIAL + 0.04320xTRAN_USER + 0.4855xHOME_RPASS + 0.3777xMEMBER_LESS_3

ROL model: – 0.3140xDIST_STA + 0.4875xTRAN_AVAxTRAN_USER + 0.3475xDIST_EXPxNO_CAR + 0.3304xDIST_EXPxCAR_OWN + 0.2015xCOM_TIME45m – 1.7837xLAND_PRICE + 1.6495xMED_INC + 1.2159xEMP_DENSxLOW_INC + 0.6582xEMP_DENSxMID_INC + 0.3153xEMP_DENSxHIGH_INC + 1.7516xSCHOOL_DENS – 0.1021xINDUSTRIAL

RONL model: – 0.1821xDIST_STA + 0.0845xTRAN_AVAxTRAN_USER + 0.0978xDIST_EXPxNO_CAR + 0.0789xDIST_EXPxCAR_OWN + 0.0319xCOM_TIME45m – 0.3394xLAND_PRICE + 0.5226xMED_INC + 0.2823xEMP_DENSxLOW_INC + 0.1450xEMP_DENSxMID_INC + 0.0628xEMP_DENSxHIGH_INC + 0.4168xSCHOOL_DENS – 0.0219xINDUSTRIAL + 0.4673xTRAN_USER + 0.2972xHOME_RPASS + 0.1675xMEMBER_LESS_3

For residential location choice model by difference between current and new home location among travel mode choices;

ML model: – 0.2475xDIFF_DIST_STAxPRI_USER – 0.1283xDIFF_DIST_STAxPUB_USER – 0.9129xDIFF_DIST_STAxTRAN_USER + 0.8199xDIST_EXPxNO_CAR + 0.7726xDIST_EXPxCAR_OWN + 0.4019xCOM_TIME45m – 1.4955xLAND_PRICE + 1.9729xMED_INC + 1.5742xEMP_DENSxLOW_INC + 0.9268xEMP_DENSxMID_INC + 0.6646xEMP_DENSxHIGH_INC + 1.9918xSCHOOL_DENS – 0.1259xINDUSTRIAL

NL model: – 0.2161xDIFF_DIST_STAxPRI_USER – 0.1668xDIFF_DIST_STAxPUB_USER – 0.4326xDIFF_DIST_STAxTRAN_USER + 0.2517xDIST_EXPxNO_CAR + 0.2180xDIST_EXPxCAR_OWN + 0.1010xCOM_TIME45m – 0.3910xLAND_PRICE + 0.6342xMED_INC + 0.4514xEMP_DENSxLOW_INC + 0.2535xEMP_DENSxMID_INC + 0.1791xEMP_DENSxHIGH_INC + 0.5830xSCHOOL_DENS – 0.0347xINDUSTRIAL + 0.2850xTRAN_USER + 0.4890xHOME_RPASS + 0.3858xMEMBER_LESS_3

ROL model: – 0.2872xDIFF_DIST_STAxPRI_USER – 0.1710xDIFF_DIST_STAxPUB_USER – 0.7699xDIFF_DIST_STAxTRAN_USER + 0.3559xDIST_EXPxNO_CAR + 0.3442xDIST_EXPxCAR_OWN + 0.2221xCOM_TIME45m – 1.6129xLAND_PRICE + 1.7571xMED_INC + 1.2382xEMP_DENSxLOW_INC + 0.6728xEMP_DENSxMID_INC + 0.3250xEMP_DENSxHIGH_INC + 1.6089xSCHOOL_DENS – 0.1097xINDUSTRIAL

RONL model: – 0.2114xDIFF_DIST_STAxPRI_USER – 0.1380xDIFF_DIST_STAxPUB_USER – 0.3065xDIFF_DIST_STAxTRAN_USER + 0.1046xDIST_EXPxNO_CAR + 0.0888xDIST_EXPxCAR_OWN + 0.0382xCOM_TIME45m – 0.3422xLAND_PRICE + 0.5444xMED_INC + 0.3044xEMP_DENSxLOW_INC + 0.1589xEMP_DENSxMID_INC + 0.0711xEMP_DENSxHIGH_INC + 0.4112xSCHOOL_DENS – 0.0242xINDUSTRIAL + 0.4706xTRAN_USER + 0.2451xHOME_RPASS + 0.2857xMEMBER_LESS_3

For residential location choice model by difference between current and new home location among household income;

ML model: – 0.4540xDIFF_DIST_STAxLOW_INC – 0.3741xDIFF_DIST_STAxMID_INC – 0.3690xDIFF_DIST_STAxHIGH_INC + 0.8059xDIST_EXPxNO_CAR + 0.7818xDIST_EXPxCAR_OWN + 0.4115xCOM_TIME45m – 1.4973xLAND_PRICE + 1.9117xMED_INC + 1.5399xEMP_DENSxLOW_INC + 0.9297xEMP_DENSxMID_INC + 0.6654xEMP_DENSxHIGH_INC + 1.9863xSCHOOL_DENS – 0.1261xINDUSTRIAL

NL model: – 0.3047xDIFF_DIST_STAxLOW_INC – 0.2112xDIFF_DIST_STAxMID_INC – 0.2595xDIFF_DIST_STAxHIGH_INC + 0.2380xDIST_EXPxNO_CAR + 0.2121xDIST_EXPxCAR_OWN + 0.0954xCOM_TIME45m – 0.3805xLAND_PRICE + 0.6072xMED_INC + 0.4226xEMP_DENSxLOW_INC + 0.2491xEMP_DENSxMID_INC + 0.1749xEMP_DENSxHIGH_INC + 0.5462xSCHOOL_DENS – 0.0331xINDUSTRIAL + 0.4773xTRAN_USER + 0.4926xHOME_RPASS + 0.3932xMEMBER_LESS_3

ROL model: – 0.4610xDIFF_DIST_STAxLOW_INC – 0.3842xDIFF_DIST_STAxMID_INC – 0.3720xDIFF_DIST_STAxHIGH_INC + 0.3505xDIST_EXPxNO_CAR + 0.3511xDIST_EXPxCAR_OWN + 0.2272xCOM_TIME45m – 1.6210xLAND_PRICE +

1.7043xMED_INC + 1.2073xEMP_DENSxLOW_INC + 0.6725xEMP_DENSxMID_INC + 0.3274xEMP_DENSxHIGH_INC + 1.6064xSCHOOL_DENS – 0.1095xINDUSTRIAL

RONL model: – 0.2609xDIFF_DIST_STAxLOW_INC – 0.1957xDIFF_DIST_STAxMID_INC – 0.2096xDIFF_DIST_STAxHIGH_INC + 0.1029xDIST_EXPxNO_CAR + 0.0868xDIST_EXPxCAR_OWN + 0.0374xCOM_TIME45m – 0.3330xLAND_PRICE + 0.5286xMED_INC + 0.2893xEMP_DENSxLOW_INC + 0.1561xEMP_DENSxMID_INC + 0.0700xEMP_DENSxHIGH_INC + 0.3973xSCHOOL_DENS – 0.0236xINDUSTRIAL + 0.4704xTRAN_USER + 0.3388xHOME_RPASS + 0.1730xMEMBER_LESS_3

6.8.1.1 Effects of Local Transportation Accessibility

First, the proximity to the nearest rail station (DIST_STA) has negative effect to the residential location decision and the effect is statistically significant as it is intuitive that households tend to locate near the rail transit stations. Furthermore, the model results also support that the distance to the nearest station from the alternative location that households choose to live is closer to the station compared with the distance to the nearest station from their current location (DIFF_DIST_STA). However, this effect varies depending on travel mode choices. Not surprising, the chance of residing closer to the station increases in the rail transit user group. It is interesting note that this chance is followed by the private mode user and public mode user group. This is because public transportation becomes a main transport for poor people while housing along the rail transit is totally higher. Therefore, it is very difficult for them to move closer to the station compared to other mode user groups. In addition, households mainly get to work by transit are more likely to reside in areas having stations within a 2 kilometer walking distance, as TRAN_AVA x TRAN_USER has positive sign.

Next, the results also show that higher levels of car ownership increase the chance of residing near the expressway access (relative to the categories of the distance to expressway access interacted with car ownership). In the other word, it is interesting note that car ownership likely influences the decision to live closer to the access. In fact, Bangkok is the most heavily congested cities; the expressway allows households to reduce journey time.

6.8.1.2 Effects of Work Accessibility

Trials of models were attempted for 45, 60, and 90 minute as well, however the best-fitting and most interpretable statistical results were obtained for the alternative zones can reach to the CBD within 45 minute. Obviously, person living in Bangkok spends more than 1 hours travelling to/from work. This could reflect the willingness of households; however, the better should be less than 60 minute.

6.8.1.3 Effects of Housing Affordability

Housing affordability is another major factor influencing residential location choice. As expected, the land price has a negative coefficient, indicating that more expensive locations are less likely to choose, i.e., as the land price rises, the likelihood of that zone being chosen by households as a residential location falls.

6.8.1.4 Effects of Neighborhood Amenity

A clustering effect is observed with respect to the zonal household income. The results support the income segregation phenomenon observed in previous study, e.g. (Bhat and Guo, 2004); Morrow-Jones and Kim (2009). Interestingly, the employment density interacted with socio-demographic coefficients (EMP_DENS x LOW_INC, EMP_DENS x MID_INC, and EMP_DENS x HIGH_INC) indicate that households tend to reside in areas with high employment density however this effect decreases as the household income increases. Not surprising, the locations with higher school density are remarkably preferred to those with lower school density. Finally, the industrial land use measure is negatively associated with residential location choice, indicating that locations with higher number of industrial area are generally less preferred, i.e., as the area of the industrial land use increases, the likelihood of being selected decreases.

Table 6 - 9 Residential Location Choice Model by Access to Closet Station (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_STA	-0.2980	-4.6026	***	-0.2156	-3.9353	***
TRAN_AVA x TRAN_USER	0.5339	5.5342	***	0.0852	2.3337	**
DIST_EXP x NO_CAR	0.7988	6.8491	***	0.2369	3.9701	***
DIST_EXP x CAR_OWN	0.7520	8.3990	***	0.2045	3.8262	***
Work and non-work accessibility						
COM_TIME45m	0.3759	4.5432	***	0.0927	3.2471	***
Housing affordability						
LAND_PRICE	-1.6714	-5.5270	***	-0.3894	-2.9097	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.8870	2.5375	**	0.5971	2.2522	**
EMP_DENS x LOW_INC	1.5505	5.3788	***	0.4257	3.2042	***
EMP_DENS x MID_INC	0.9092	8.7454	***	0.2372	3.6000	***
EMP_DENS x HIGH_INC	0.6510	7.4049	***	0.1672	3.2554	***
SCHOOL_DENS	2.1469	11.1066	***	0.5775	4.5389	***
Land attribute						
INDUSTRIAL	-0.1175	-5.0655	***	-0.0319	-3.3491	***
Upper nest						
Rail station within district						
TRAN_USER				0.4320	3.5036	***
HOME_RPASS				0.4855	3.0902	***
MEMBER_LESS_3				0.3777	3.3359	***
Dissimilarity						
Rail station within district (λ)				0.2981	5.6758	***
Rho-square (Nagelkerke)		0.2382			0.2575	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 10 Residential Location Choice Model by Access to Closet Station (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_STA	-0.3140	-7.0601	***	-0.1821	-5.2485	***
TRAN_AVA x TRAN_USER	0.4875	7.0314	***	0.0845	3.4225	***
DIST_EXP x NO_CAR	0.3475	4.2272	***	0.0978	3.7427	***
DIST_EXP x CAR_OWN	0.3304	5.4021	***	0.0789	3.5457	***
Work and non-work accessibility						
COM_TIME45m	0.2015	3.4138	***	0.0319	2.0473	**
Housing affordability						
LAND_PRICE	-1.7837	-8.3579	***	-0.3394	-3.7105	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.6495	3.0335	***	0.5226	3.0226	***
EMP_DENS x LOW_INC	1.2159	6.0490	***	0.2823	3.4840	***
EMP_DENS x MID_INC	0.6582	9.2109	***	0.1450	3.9831	***
EMP_DENS x HIGH_INC	0.3153	5.3248	***	0.0628	2.8941	***
SCHOOL_DENS	1.7516	12.1315	***	0.4168	5.3913	***
Land attribute						
INDUSTRIAL	-0.1021	-6.8941	***	-0.0219	-3.9059	***
Upper nest						
Rail station within district						
TRAN_USER				0.4673	4.3991	***
HOME_RPASS				0.2972	3.5632	***
MEMBER_LESS_3				0.1675	2.1972	**
Dissimilarity						
Rail station within district (λ)				0.2825	7.5750	***
Rho-square (Nagelkerke)		0.2766			0.3020	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 11 Residential Location Choice Model by Difference between Current and New Home Location among Travel Mode Choices (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIFF_DIST_STA x PRI_USER	-0.2475	-3.0033	***	-0.2161	-3.4269	***
DIFF_DIST_STA x PUB_USER	-0.1283	-1.2851	n/s	-0.1668	-2.5257	**
DIFF_DIST_STA x TRAN_USER	-0.9129	-7.8905	***	-0.4326	-3.8915	***
DIST_EXP x NO_CAR	0.8199	6.9329	***	0.2517	4.0529	***
DIST_EXP x CAR_OWN	0.7726	8.5523	***	0.2180	3.9337	***
Work and non-work accessibility						
COM_TIME45m	0.4019	4.8859	***	0.1010	3.3493	***
Housing affordability						
LAND_PRICE	-1.4955	-5.0015	***	-0.3910	-2.9082	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.9729	2.6358	***	0.6342	2.3127	**
EMP_DENS x LOW_INC	1.5742	5.4420	***	0.4514	3.2842	***
EMP_DENS x MID_INC	0.9268	8.9048	***	0.2535	3.7362	***
EMP_DENS x HIGH_INC	0.6646	7.5478	***	0.1791	3.3932	***
SCHOOL_DENS	1.9918	10.4479	***	0.5830	4.5545	***
Land attribute						
INDUSTRIAL	-0.1259	-5.4814	***	-0.0347	-3.4816	***
Upper nest						
Rail station within district						
TRAN_USER				0.2850	1.9004	*
HOME_RPASS				0.4890	3.1114	***
MEMBER_LESS_3				0.3858	3.4103	***
Dissimilarity						
Rail station within district (λ)				0.3094	5.6350	
Rho-square (Nagelkerke)		0.2408			0.2581	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 12 Residential Location Choice Model by Difference between Current and New Home Location among Travel Mode Choices (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIFF_DIST_STA x PRI_USER	-0.2872	-5.0027	***	-0.2114	-5.3637	***
DIFF_DIST_STA x PUB_USER	-0.1710	-2.4365	**	-0.1380	-3.3389	***
DIFF_DIST_STA x TRAN_USER	-0.7699	-9.9682	***	-0.3065	-4.6673	***
DIST_EXP x NO_CAR	0.3559	4.2761	***	0.1046	3.8722	***
DIST_EXP x CAR_OWN	0.3442	5.5803	***	0.0888	3.8667	***
Work and non-work accessibility						
COM_TIME45m	0.2221	3.7847	***	0.0382	2.3674	**
Housing affordability						
LAND_PRICE	-1.6129	-7.6379	***	-0.3422	-3.8639	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.7571	3.2155	***	0.5444	3.0816	***
EMP_DENS x LOW_INC	1.2382	6.1423	***	0.3044	3.7247	***
EMP_DENS x MID_INC	0.6728	9.4085	***	0.1589	4.3380	***
EMP_DENS x HIGH_INC	0.3250	5.4785	***	0.0711	3.1846	***
SCHOOL_DENS	1.6089	11.2781	***	0.4112	5.4946	***
Land attribute						
INDUSTRIAL	-0.1097	-7.4645	***	-0.0242	-4.2183	***
Upper nest						
Rail station within district						
TRAN_USER				0.4706	4.4262	***
HOME_RPASS				0.2451	2.6017	***
MEMBER_LESS_3				0.1793	2.3472	**
Dissimilarity						
Rail station within district (λ)				0.2857	7.5420	***
Rho-square (Nagelkerke)		0.2729			0.2987	

*** = significant at 1% level
** = significant at 5% level
* = significant at 10% level
n/s = no significant

Table 6 - 13 Residential Location Choice Model by Difference between Current and New Home Location among Household Income (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIFF_DIST_STA x LOW_INC	-0.4540	-1.2327	n/s	-0.3047	-1.6231	n/s
DIFF_DIST_STA x MID_INC	-0.3741	-3.7173	***	-0.2112	-3.2112	***
DIFF_DIST_STA x HIGH_INC	-0.3690	-4.8760	***	-0.2595	-4.2044	***
DIST_EXP x NO_CAR	0.8059	6.8332	***	0.2380	4.1381	***
DIST_EXP x CAR_OWN	0.7818	8.6623	***	0.2121	4.0776	***
Work and non-work accessibility						
COM_TIME45m	0.4115	5.0122	***	0.0954	3.3961	***
Housing affordability						
LAND_PRICE	-1.4973	-5.0109	***	-0.3805	-3.0363	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.9117	2.5537	**	0.6072	2.3491	**
EMP_DENS x LOW_INC	1.5399	4.6965	***	0.4226	3.3201	***
EMP_DENS x MID_INC	0.9297	8.6084	***	0.2491	3.8748	***
EMP_DENS x HIGH_INC	0.6654	7.4317	***	0.1749	3.5178	***
SCHOOL_DENS	1.9863	10.4215	***	0.5462	4.6828	***
Land attribute						
INDUSTRIAL	-0.1261	-5.4894	***	-0.0331	-3.5735	***
Upper nest						
Rail station within district						
TRAN_USER				0.4773	3.9792	***
HOME_RPASS				0.4926	3.1351	***
MEMBER_LESS_3				0.3932	3.4517	***
Dissimilarity						
Rail station within district (λ)				0.2863	5.7849	***
Rho-square (Nagelkerke)		0.2275			0.2553	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 14 Residential Location Choice Model by Difference between Current and New Home Location among Household Income (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIFF_DIST_STA x LOW_INC	-0.4610	-1.8434	*	-0.2609	-2.1381	**
DIFF_DIST_STA x MID_INC	-0.3842	-5.5043	***	-0.1957	-4.4352	***
DIFF_DIST_STA x HIGH_INC	-0.3720	-7.1399	***	-0.2096	-5.4861	***
DIST_EXP x NO_CAR	0.3505	4.2215	***	0.1029	3.9130	***
DIST_EXP x CAR_OWN	0.3511	5.6967	***	0.0868	3.8577	***
Work and non-work accessibility						
COM_TIME45m	0.2272	3.8753	***	0.0374	2.3913	**
Housing affordability						
LAND_PRICE	-1.6210	-7.6785	***	-0.3330	-3.8728	***
Neighborhood amenity (including demographic interactions)						
MED_INC	1.7043	3.1176	***	0.5286	3.0735	***
EMP_DENS x LOW_INC	1.2073	5.3439	***	0.2893	3.6802	***
EMP_DENS x MID_INC	0.6725	9.0546	***	0.1561	4.3393	***
EMP_DENS x HIGH_INC	0.3274	5.4258	***	0.0700	3.1782	***
SCHOOL_DENS	1.6064	11.2591	***	0.3973	5.5454	***
Land attribute						
INDUSTRIAL	-0.1095	-7.4577	***	-0.0236	-4.2332	***
Upper nest						
Rail station within district						
TRAN_USER				0.4704	4.4238	***
HOME_RPASS				0.3388	4.1548	***
MEMBER_LESS_3				0.1730	2.2436	**
Dissimilarity						
Rail station within district (λ)				0.2765	7.7107	***
Rho-square (Nagelkerke)		0.2580			0.2957	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

6.8.1.5 Effects of Rail Station within District (Upper Nest)

In term of the variables in the upper nest, districts without rail transit station, was considered the reference choice and three household specific variables were specified for these interpretations. All of these variables have the expected positive sign and they are all statistically significant.

The first variable, TRAN_USER, captures the travel behavior in daily activity destination, namely, work location. As expected, this estimated coefficient suggests that households whose get around by transit are more likely to stay near the rail transit station than far away, which corresponds to the empirical evidence in the literature that says as the number of commuters in the household who have transit connectivity increases, the likelihood of residential location in a zone with transit availability increases as well (Sener *et al.*, 2011).

The next variable, HOME_RPASS, is related to current home location of households. The estimated parameter reveals that households whose current home location is served by the rail transit system tend to be drawn to the rail transit station areas. This result reflects other studies that showed the strong preference of the households to move in the same district or the same neighborhood in which they lived before (de Palma *et al.*, 2005).

The last variable, MEMBER_LESS_3, the model suggests that the households with three or more than shy away from locations near rail transit stations. This could be reflect land use planning policies that promote high-rise building development especially near rail stations, i.e., residential (e.g. condominium and apartment) and commercial (e.g. office building). Furthermore, the characteristics of condominium and apartment are typically smaller than houses (e.g. detached house, semi-detached house and townhouse) which might suitable for single and couple households.

6.8.2 Comparison and Measures of fit

This section intends to compare the estimated results obtained from traditional discrete choice model, namely, multinomial logit (ML) and nested logit (NL) model to the results with discrete choice model for a ranking of alternatives, i.e., rank-ordered logit (ROL) and ranked-ordered nested logit (RONL). First, all of the four models yield the same behavioral interpretations, reflected by the sign of parameter estimated, as discussed in the previous section. For the significance level, it can be seen that the ROL and the RONL model are all significant as in the ML and NL model. Let consider the dissimilarity or correlation parameter, λ_m, is an indicator whether nesting is appropriate or not. As stated in the derivation, the dissimilarity parameter for the ROL model is one as the ML model because both models assume independence (IIA) across all choice alternatives. The NL and RONL model partially relax the IIA assumption by maintain IIA for choices with same nest, but relaxing it for choices across nests. It was then found that the significance of the dissimilarity parameter in the corresponding models indicates the effectiveness of the model structure. In addition, the dissimilarity is smaller than 1 in the NL model and this parameter is statistically significantly different at the 0.01 level of significance. Likewise, it found that the RONL model offers the same results. On top of that, the finding of a dissimilarity parameter that is statistically significantly smaller than one indicates which strongly supports the hierarchical nest structure. In term of goodness of fit, the rho-square (ρ^2) is calculated. It is clear that the model fit is improved as the model complexity increases, that is, the RONL model has the best performance over the other reference models. Furthermore, this proves that the application of discrete choice for ranking of alternatives can be employed for the context of analyzing location choices.

All of these are a consequence of the main difference between experiments from the ranking of alternatives and choosing the most preferred, i.e., the measurement indicators for the dependent variable. Remember that ranking involves the ordering a finite set of alternatives in the choice set while choosing requires only the choice of the most preferred. This results also support similar findings that ranking data provides more statistical information than choice experiments, which lead to tighter confidence intervals around the parameter estimates (Merino-Castello, 2003).

6.9 Effects of Urban Rail Transit Investment on Residential Location Decision

This section intends to interpret the effects of urban rail transit investment on residential location decision by expressing the preferences toward the locations among the existing urban rail transit (i.e. BTS Skytrain, MRT Blue Line and Airport Rail Link) and under construction urban rail transit (i.e. SRT Red Line and MRT Purple Line) in Bangkok Metropolitan Region. Such preference effects were thought depending on each individual and/or household, thus, the interpretation will be investigated among travel mode choice preferences (i.e. private car users, public transport users and urban trail transit users) and household income levels (i.e. low income, middle income and high income) as presented in Table 6 - 16 to Table 6 - 20.

In addition, from the Table 6 - 16 to Table 6 - 20, the equations of residential location choice model can be written as below.

For residential location choice model by access to each line;

ML model: – 1.1903xDIST_GSTA – 0.1207xDIST_BSTA + 0.1925xDIST_ASTA + 0.5489xDIST_RSTA – 0.3451xDIST_PSTA + 1.2395xDIST_EXPxNO_CAR + 1.2137xDIST_EXPxCAR_OWN + 0.2911xCOM_TIME45m – 0.7476xLAND_PRICE + 0.3522xMED_INC + 1.1862xEMP_DENSxLOW_INC + 0.5529xEMP_DENSxMID_INC + 0.2960xEMP_DENSxHIGH_INC + 1.2098xSCHOOL_DENS – 0.1224xINDUSTRIAL

NL model: – 0.4120xDIST_GSTA – 0.0041xDIST_BSTA + 0.0312xDIST_ASTA + 0.1774xDIST_RSTA – 0.1453xDIST_PSTA + 0.3907xDIST_EXPxNO_CAR + 0.3485xDIST_EXPxCAR_OWN + 0.1149xCOM_TIME45m – 0.3883xLAND_PRICE + 0.0612xMED_INC + 0.4149xEMP_DENSxLOW_INC + 0.1880xEMP_DENSxMID_INC + 0.1059xEMP_DENSxHIGH_INC + 0.4621xSCHOOL_DENS – 0.0393xINDUSTRIAL + 0.4398xTRAN_USER + 0.4692xHOME_RPASS + 0.3403xMEMBER_LESS_3

ROL model: – 0.9155xDIST_GSTA – 0.2620xDIST_BSTA + 0.1569xDIST_ASTA + 0.4128xDIST_RSTA – 0.3057xDIST_PSTA + 0.8080xDIST_EXPxNO_CAR + 0.8054xDIST_EXPxCAR_OWN + 0.1519xCOM_TIME45m – 1.2756xLAND_PRICE + 0.1539xMED_INC + 1.0021xEMP_DENSxLOW_INC + 0.4456xEMP_DENSxMID_INC + 0.1052xEMP_DENSxHIGH_INC + 0.8652xSCHOOL_DENS – 0.0960xINDUSTRIAL

RONL model: – 0.2626xDIST_GSTA – 0.0001xDIST_BSTA + 0.0024xDIST_ASTA + 0.0991xDIST_RSTA – 0.1148xDIST_PSTA + 0.1820xDIST_EXPxNO_CAR + 0.1600xDIST_EXPxCAR_OWN + 0.0498xCOM_TIME45m – 0.4633xLAND_PRICE + 0.1709xMED_INC + 0.2777xEMP_DENSxLOW_INC + 0.1289xEMP_DENSxMID_INC + 0.0401xEMP_DENSxHIGH_INC + 0.3051xSCHOOL_DENS – 0.0243xINDUSTRIAL + 0.4569xTRAN_USER + 0.3116xHOME_RPASS + 0.1400xMEMBER_LESS_3

For residential location choice model by access to each line among travel mode choices;

ML model: – 1.0785xDIST_GSTAxPRI_USER – 0.9724xDIST_GSTAxPUB_USER – 1.4881xDIST_GSTAxTRAN_USER + 0.1057xDIST_BSTAxPRI_USER – 0.0094xDIST_BSTAxPUB_USER – 0.4621xDIST_BSTAxTRAN_USER + 0.1537xDIST_ASTAxPRI_USER + 0.3180xDIST_ASTAxPUB_USER + 0.0982xDISTxASTAxTRAN_USER + 0.3051xDIST_RSTAxPRI_USER + 0.4841xDIST_RSTAxPUB_USER + 0.8342xDISTxRSTAxTRAN_USER – 0.2414xDIST_PSTAxPRI_USER – 0.3753xDIST_PSTAxPUB_USER – 0.4234xDIST_PSTAxTRAN_USER + 1.2281xDIST_EXPxNO_CAR + 1.1168xDIST_EXPxCAR_OWN + 0.2873xCOM_TIME45m – 0.8377xLAND_PRICE + 0.4033xMED_INC + 1.2199xEMP_DENSxLOW_INC + 0.5529xEMP_DENSxMID_INC + 0.3008xEMP_DENSxHIGH_INC + 1.2980xSCHOOL_DENS – 0.1208xINDUSTRIAL

NL model: – 0.4360xDIST_GSTAxPRI_USER – 0.3734xDIST_GSTAxPUB_USER – 0.7144xDIST_GSTAxTRAN_USER + 0.0619xDIST_BSTAxPRI_USER – 0.0225xDIST_BSTAxPUB_USER – 0.1029xDIST_BSTAxTRAN_USER – 0.0331xDIST_ASTAxPRI_USER + 0.1167xDIST_ASTAxPUB_USER – 0.0223xDISTxASTAxTRAN_USER + 0.1121xDIST_RSTAxPRI_USER + 0.2023xDIST_RSTAxPUB_USER + 0.3529xDISTxRSTAxTRAN_USER – 0.1208xDIST_PSTAxPRI_USER – 0.1720xDIST_PSTAxPUB_USER – 0.2335xDIST_PSTAxTRAN_USER + 0.4950xDIST_EXPxNO_CAR + 0.4080xDIST_EXPxCAR_OWN + 0.1347xCOM_TIME45m – 0.4873xLAND_PRICE + 0.1016xMED_INC + 0.5150xEMP_DENSxLOW_INC + 0.2215xEMP_DENSxMID_INC + 0.1264xEMP_DENSxHIGH_INC + 0.5865xSCHOOL_DENS – 0.0461xINDUSTRIAL + 0.0927xTRAN_USER + 0.4702xHOME_RPASS + 0.3456xMEMBER_LESS_3

ROL model: – 0.7909xDIST_GSTAxPRI_USER – 0.8105xDIST_GSTAxPUB_USER – 1.0692xDIST_GSTAxTRAN_USER + 0.0081xDIST_BSTAxPRI_USER + 0.0584xDIST_BSTAxPUB_USER – 0.7929xDIST_BSTAxTRAN_USER + 0.1257xDIST_ASTAxPRI_USER + 0.2030xDIST_ASTAxPUB_USER + 0.1041xDISTxASTAxTRAN_USER + 0.1008xDIST_RSTAxPRI_USER + 0.3095xDIST_RSTAxPUB_USER + 0.8696xDISTxRSTAxTRAN_USER – 0.2023xDIST_PSTAxPRI_USER – 0.3328xDIST_PSTAxPUB_USER – 0.4209xDIST_PSTAxTRAN_USER + 0.7863xDIST_EXPxNO_CAR + 0.6922xDIST_EXPxCAR_OWN + 0.1519xCOM_TIME45m – 1.3782xLAND_PRICE + 0.2253xMED_INC + 1.0176xEMP_DENSxLOW_INC + 0.4537xEMP_DENSxMID_INC + 0.1217xEMP_DENSxHIGH_INC + 0.9685xSCHOOL_DENS – 0.0972xINDUSTRIAL

RONL model: – 0.3240xDIST_GSTAxPRI_USER – 0.3017xDIST_GSTAxPUB_USER – 0.4909xDIST_GSTAxTRAN_USER + 0.0898xDIST_BSTAxPRI_USER + 0.0583xDIST_BSTAxPUB_USER – 0.1843xDIST_BSTAxTRAN_USER – 0.0113xDIST_ASTAxPRI_USER + 0.0451xDIST_ASTAxPUB_USER – 0.0197xDISTxASTAxTRAN_USER + 0.0113xDIST_RSTAxPRI_USER + 0.1126xDIST_RSTAxPUB_USER + 0.3302xDISTxRSTAxTRAN_USER – 0.1231xDIST_PSTAxPRI_USER – 0.1620xDIST_PSTAxPUB_USER – 0.2189xDIST_PSTAxTRAN_USER + 0.2859xDIST_EXPxNO_CAR + 0.2279xDIST_EXPxCAR_OWN + 0.0720xCOM_TIME45m – 0.6823xLAND_PRICE + 0.1944xMED_INC + 0.4324xEMP_DENSxLOW_INC + 0.2003xEMP_DENSxMID_INC + 0.0741xEMP_DENSxHIGH_INC + 0.4396xSCHOOL_DENS – 0.0351xINDUSTRIAL + 0.4609xTRAN_USER + 0.1055xHOME_RPASS + 0.1469xMEMBER_LESS_3

For residential location choice model by access to each line among household income;

ML model: – 1.1904xDIST_GSTAxLOW_INC – 1.2763xDIST_GSTAxMID_INC – 1.1141xDIST_GSTAxHIGH_INC – 1.6023xDIST_BSTAxLOW_INC – 0.4447xDIST_BSTAxMID_INC – 0.0878xDIST_BSTAxHIGH_INC + 0.3065xDIST_ASTAxLOW_INC + 0.2668xDIST_ASTAxMID_INC + 0.1489xDISTxASTAxHIGH_INC + 1.5165xDIST_RSTAxLOW_INC + 0.6803xDIST_RSTAxMID_INC + 0.4218xDISTxRSTAxHIGH_INC – 0.2458xDIST_PSTAxLOW_INC – 0.2852xDIST_PSTAxMID_INC – 0.3628xDIST_PSTAxHIGH_INC + 1.2995xDIST_EXPxNO_CAR + 1.1867xDIST_EXPxCAR_OWN + 0.2921xCOM_TIME45m – 0.7398xLAND_PRICE + 0.3415xMED_INC + 0.2814xEMP_DENSxLOW_INC + 0.3161xEMP_DENSxMID_INC + 0.4564xEMP_DENSxHIGH_INC + 1.2134xSCHOOL_DENS – 0.1208xINDUSTRIAL

NL model: – 0.4391xDIST_GSTAxLOW_INC – 0.4044xDIST_GSTAxMID_INC – 0.3573xDIST_GSTAxHIGH_INC – 0.6198xDIST_BSTAxLOW_INC – 0.1293xDIST_BSTAxMID_INC + 0.0787xDIST_BSTAxHIGH_INC + 0.1715xDIST_ASTAxLOW_INC + 0.0699xDIST_ASTAxMID_INC + 0.0069xDISTxASTAxHIGH_INC + 0.5682xDIST_RSTAxLOW_INC

+ 0.2136xDIST_RSTAxMID_INC + 0.1211xDISTxRSTAxHIGH_INC – 0.0939xDIST_PSTAxLOW_INC –0.0976xDIST_PSTAxMID_INC – 0.1478xDIST_PSTAxHIGH_INC + 0.3845xDIST_EXPxNO_CAR + 0.3099xDIST_EXPxCAR_OWN + 0.1100xCOM_TIME45m – 0.3588xLAND_PRICE + 0.0361xMED_INC + 0.0477xEMP_DENSxLOW_INC + 0.0956xEMP_DENSxMID_INC + 0.1435xEMP_DENSxHIGH_INC + 0.4381xSCHOOL_DENS – 0.0359xINDUSTRIAL + 0.4428xTRAN_USER + 0.4713xHOME_RPASS + 0.3489xMEMBER_LESS_3

ROL model: – 1.0355xDIST_GSTAxLOW_INC – 0.9871xDIST_GSTAxMID_INC – 0.8534xDIST_GSTAxHIGH_INC – 1.3689xDIST_BSTAxLOW_INC – 0.5163xDIST_BSTAxMID_INC – 0.1032xDIST_BSTAxHIGH_INC + 0.3569xDIST_ASTAxLOW_INC + 0.2405xDIST_ASTAxMID_INC + 0.1065xDISTxASTAxHIGH_INC + 1.8099xDIST_RSTAxLOW_INC + 0.4967xDIST_RSTAxMID_INC + 0.3121xDISTxRSTAxHIGH_INC – 0.8232xDIST_PSTAxLOW_INC – 0.2683xDIST_PSTAxMID_INC – 0.3005xDIST_PSTAxHIGH_INC + 0.8648xDIST_EXPxNO_CAR + 0.7831xDIST_EXPxCAR_OWN + 0.1530xCOM_TIME45m – 1.2695xLAND_PRICE + 0.1143xMED_INC + 0.4746xEMP_DENSxLOW_INC + 0.2872xEMP_DENSxMID_INC + 0.2091xEMP_DENSxHIGH_INC + 0.8623xSCHOOL_DENS – 0.0944xINDUSTRIAL

RONL model: – 0.3064xDIST_GSTAxLOW_INC – 0.2568xDIST_GSTAxMID_INC – 0.2111xDIST_GSTAxHIGH_INC – 0.3300xDIST_BSTAxLOW_INC – 0.0690xDIST_BSTAxMID_INC + 0.0425xDIST_BSTAxHIGH_INC + 0.1164xDIST_ASTAxLOW_INC + 0.0267xDIST_ASTAxMID_INC – 0.0122xDISTxASTAxHIGH_INC + 0.5326xDIST_RSTAxLOW_INC + 0.1186xDIST_RSTAxMID_INC + 0.0545xDISTxRSTAxHIGH_INC – 0.2477xDIST_PSTAxLOW_INC – 0.0871xDIST_PSTAxMID_INC – 0.1005xDIST_PSTAxHIGH_INC + 0.1705xDIST_EXPxNO_CAR + 0.1274xDIST_EXPxCAR_OWN + 0.0453xCOM_TIME45m – 0.4153xLAND_PRICE + 0.1766xMED_INC + 0.1197xEMP_DENSxLOW_INC + 0.0693xEMP_DENSxMID_INC + 0.0572xEMP_DENSxHIGH_INC + 0.2851xSCHOOL_DENS – 0.0212xINDUSTRIAL + 0.4563xTRAN_USER + 0.3132xHOME_RPASS + 0.1433xMEMBER_LESS_3

Table 6 - 15 Residential Location Choice Model by Access to Each Line (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA	-1.1903	-11.2064	***	-0.4120	-3.4333	***
DIST_BSTA	-0.1207	-0.4366	n/s	0.0041	0.0378	n/s
DIST_ASTA	0.1925	2.0311	**	0.0312	0.7366	n/s
DIST_RSTA	0.5489	4.1881	***	0.1774	2.7174	***
DIST_PSTA	-0.3451	-4.9583	***	-0.1453	-2.8065	***
DIST_EXP x NO_CAR	1.2395	6.5243	***	0.3907	2.7860	***
DIST_EXP x CAR_OWN	1.2137	6.8868	***	0.3485	2.6031	***
Work and non-work accessibility						
COM_TIME45m	0.2911	3.3955	***	0.1149	2.9146	***
Housing affordability						
LAND_PRICE	-0.7476	-2.1310	**	-0.3883	-2.3669	**
Neighborhood amenity (including demographic interactions)						
MED_INC	0.3522	0.4280	n/s	0.0612	0.1920	n/s
EMP_DENS x LOW_INC	1.1862	4.0026	***	0.4149	2.4228	**
EMP_DENS x MID_INC	0.5529	4.5268	***	0.1880	2.4282	**
EMP_DENS x HIGH_INC	0.2960	2.7464	***	0.1059	1.8616	*
SCHOOL_DENS	1.2098	4.9235	***	0.4621	3.3748	***
Land attribute						
INDUSTRIAL	-0.1224	-4.4219	***	-0.0393	-2.7001	***
Upper nest						
Rail station within district						
TRAN_USER				0.4398	3.6607	***
HOME_RPASS				0.4692	2.9850	***
MEMBER_LESS_3				0.3403	2.9942	***
Dissimilarity						
Rail station within district (λ)				0.3689	4.6361	***
Rho-square (Nagelkerke)		0.2631			0.2805	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 16 Residential Location Choice Model by Access to Each Line (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA	-0.9155	-12.4333	***	-0.2626	-4.8462	***
DIST_BSTA	-0.2620	-1.3193	n/s	-0.0001	-0.0005	n/s
DIST_ASTA	0.1569	2.4110	**	0.0024	0.1064	n/s
DIST_RSTA	0.4128	4.5273	***	0.0991	2.9330	***
DIST_PSTA	-0.3057	-6.4505	***	-0.1148	-4.0859	***
DIST_EXP x NO_CAR	0.8080	5.9182	***	0.1820	3.0043	***
DIST_EXP x CAR_OWN	0.8054	6.4058	***	0.1600	2.7622	***
Work and non-work accessibility						
COM_TIME45m	0.1519	2.4621	**	0.0498	2.4971	**
Housing affordability						
LAND_PRICE	-1.2756	-5.1309	***	-0.4633	-4.2164	***
Neighborhood amenity (including demographic interactions)						
MED_INC	0.1539	0.2531	n/s	0.1709	0.8526	n/s
EMP_DENS x LOW_INC	1.0021	4.8954	***	0.2777	3.0898	***
EMP_DENS x MID_INC	0.4456	5.3935	***	0.1289	3.3734	***
EMP_DENS x HIGH_INC	0.1052	1.4726	n/s	0.0401	1.7538	*
SCHOOL_DENS	0.8652	4.8773	***	0.3051	4.4906	***
Land attribute						
INDUSTRIAL	-0.0960	-5.4882	***	-0.0243	-3.6739	***
Upper nest						
Rail station within district						
TRAN_USER				0.4569	4.2954	***
HOME_RPASS				0.3116	3.8139	***
MEMBER_LESS_3				0.1400	1.8254	*
Dissimilarity						
Rail station within district (λ)				0.3229	7.2371	***
Rho-square (Nagelkerke)		0.2961			0.3215	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 17 Residential Location Choice Model by Access to Each Line among Travel Mode Choices (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA x PRI_USER	-1.0785	-7.2492	***	-0.4360	-2.9152	***
DIST_GSTA x PUB_USER	-0.9724	-5.1401	***	-0.3734	-2.5973	***
DIST_GSTA x TRAN_USER	-1.4881	-7.9026	***	-0.7144	-3.2219	***
DIST_BSTA x PRI_USER	0.1057	0.3419	n/s	0.0619	0.4214	n/s
DIST_BSTA x PUB_USER	-0.0094	-0.0274	n/s	-0.0225	0.1415	n/s
DIST_BSTA x TRAN_USER	-0.4621	-1.3508	n/s	-0.1029	-0.6274	n/s
DIST_ASTA x PRI_USER	0.1537	1.2473	n/s	0.0331	0.5167	n/s
DIST_ASTA x PUB_USER	0.3180	2.1065	**	0.1167	1.4147	n/s
DIST_ASTA x TRAN_USER	0.0982	0.6062	n/s	-0.0223	-0.2823	n/s
DIST_RSTA x PRI_USER	0.3051	1.9713	*	0.1121	1.4607	n/s
DIST_RSTA x PUB_USER	0.4841	2.5965	***	0.2023	2.0474	**
DIST_RSTA x TRAN_USER	0.8342	4.3661	***	0.3529	2.6610	***
DIST_PSTA x PRI_USER	-0.2414	-2.4501	**	-0.1208	-1.9064	*
DIST_PSTA x PUB_USER	-0.3753	-3.1109	***	-0.1720	-2.2803	**
DIST_PSTA x TRAN_USER	-0.4234	-2.9353	***	-0.2335	-2.2974	**
DIST_EXP x NO_CAR	1.2281	6.5201	***	0.4950	2.7347	***
DIST_EXP x CAR_OWN	1.1168	6.4240	***	0.4080	2.4959	**
Work and non-work accessibility						
COM_TIME45m	0.2873	3.3235	***	0.1347	2.7354	***
Housing affordability						
LAND_PRICE	-0.8377	-2.3777	**	-0.4873	-2.4343	**
Neighborhood amenity (including demographic interactions)						
MED_INC	0.4033	0.4859	n/s	0.1016	0.2613	n/s
EMP_DENS x LOW_INC	1.2199	4.0607	***	0.5150	2.3967	**
EMP_DENS x MID_INC	0.5529	4.5138	***	0.2215	2.4149	**
EMP_DENS x HIGH_INC	0.3008	2.7902	***	0.1264	1.8866	*
SCHOOL_DENS	1.2980	5.2948	***	0.5865	3.1891	***
Land attribute						
INDUSTRIAL	-0.1208	-4.3831	***	-0.0461	-2.4899	**
Upper nest						
Rail station within district						
TRAN_USER				0.0927	0.4973	n/s
HOME_RPASS				0.4702	2.9905	***
MEMBER_LESS_3				0.3456	3.0480	***
Dissimilarity						
Rail station within district (λ)				0.4470	4.0149	***
Rho-square (Nagelkerke)		0.2981			0.3066	

*** = significant at 1% level
** = significant at 5% level
* = significant at 10% level
n/s = no significant

Table 6 - 18 Residential Location Choice Model by Access to Each Line among Travel Mode Choices (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA x PRI_USER	-0.7909	-7.5798	***	-0.3240	-3.8693	***
DIST_GSTA x PUB_USER	-0.8105	-6.2249	***	-0.3017	-3.3631	***
DIST_GSTA x TRAN_USER	-1.0692	-8.4925	***	-0.4909	-4.2709	***
DIST_BSTA x PRI_USER	0.0081	0.0363	n/s	0.0898	0.8905	n/s
DIST_BSTA x PUB_USER	0.0584	0.2361	n/s	0.0583	0.5293	n/s
DIST_BSTA x TRAN_USER	-0.7929	-3.2669	***	-0.1843	-1.4549	n/s
DIST_ASTA x PRI_USER	0.1257	1.4738	n/s	-0.0113	-0.2741	n/s
DIST_ASTA x PUB_USER	0.2030	1.9488	*	0.0451	0.8993	n/s
DIST_ASTA x TRAN_USER	0.1041	0.9638	n/s	-0.0197	-0.3779	n/s
DIST_RSTA x PRI_USER	0.1008	0.9335	n/s	0.0113	0.2451	n/s
DIST_RSTA x PUB_USER	0.3095	2.3943	**	0.1126	1.8946	*
DIST_RSTA x TRAN_USER	0.8696	6.4701	***	0.3302	3.6585	***
DIST_PSTA x PRI_USER	-0.2023	-2.9853	***	-0.1231	-2.9633	***
DIST_PSTA x PUB_USER	-0.3328	-3.9506	***	-0.1620	-3.2074	***
DIST_PSTA x TRAN_USER	-0.4209	-4.3484	***	-0.2189	-3.3685	***
DIST_EXP x NO_CAR	0.7863	5.8000	***	0.2859	3.2007	***
DIST_EXP x CAR_OWN	0.6922	5.5770	***	0.2279	2.8557	***
Work and non-work accessibility						
COM_TIME45m	0.1589	2.5583	**	0.0720	2.5117	**
Housing affordability						
LAND_PRICE	-1.3782	-5.5223	***	-0.6823	-4.3242	***
Neighborhood amenity (including demographic interactions)						
MED_INC	0.2253	0.3697	n/s	0.1944	0.7145	n/s
EMP_DENS x LOW_INC	1.0176	4.9213	***	0.4324	3.2541	***
EMP_DENS x MID_INC	0.4537	5.4739	***	0.2003	3.6442	***
EMP_DENS x HIGH_INC	0.1217	1.7029	*	0.0741	2.2067	**
SCHOOL_DENS	0.9685	5.4668	***	0.4396	4.1528	***
Land attribute						
INDUSTRIAL	-0.0972	-5.5817	***	0.0351	-3.2874	***
Upper nest						
Rail station within district						
TRAN_USER				0.4609	4.3332	***
HOME_RPASS				0.1055	0.9571	n/s
MEMBER_LESS_3				0.1469	1.9152	*
Dissimilarity						
Rail station within district (λ)				0.4252	5.5112	***
Rho-square (Nagelkerke)		0.3561			0.3668	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 19 Residential Location Choice Model by Access to Each Line among Household Income (ML and NL model)

Variables	ML			NL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA x LOW_INC	-1.1904	-2.2128	**	-0.4391	-1.9326	*
DIST_GSTA x MID_INC	-1.2763	-7.5167	***	-0.4044	-3.4750	***
DIST_GSTA x HIGH_INC	-1.1141	-8.4479	***	-0.3573	-3.2574	***
DIST_BSTA x LOW_INC	-1.6023	-1.6842	*	-0.6198	-1.5867	n/s
DIST_BSTA x MID_INC	-0.4447	-1.3113	n/s	-0.1293	-1.0109	n/s
DIST_BSTA x HIGH_INC	0.0878	0.2910	n/s	0.0787	0.6982	n/s
DIST_ASTA x LOW_INC	0.3065	0.6775	n/s	0.1715	0.9887	n/s
DIST_ASTA x MID_INC	0.2668	1.8914	*	0.0699	1.2102	n/s
DIST_ASTA x HIGH_INC	0.1489	1.3335	n/s	0.0069	0.1570	n/s
DIST_RSTA x LOW_INC	1.5165	2.5962	***	0.5682	2.5122	**
DIST_RSTA x MID_INC	0.6803	3.8510	***	0.2136	2.6401	***
DIST_RSTA x HIGH_INC	0.4218	2.8622	***	0.1211	2.0797	**
DIST_PSTA x LOW_INC	-0.2458	-0.5260	n/s	-0.0939	-0.5476	n/s
DIST_PSTA x MID_INC	-0.2852	-2.4242	**	-0.0976	-1.8259	*
DIST_PSTA x HIGH_INC	-0.3628	-4.3267	***	-0.1478	-2.6955	***
DIST_EXP x NO_CAR	1.2995	6.7947	***	0.3845	2.8730	***
DIST_EXP x CAR_OWN	1.1867	6.7148	***	0.3099	2.6026	***
Work and non-work accessibility						
COM_TIME45m	0.2921	3.4015	***	0.1100	2.9969	***
Housing affordability						
LAND_PRICE	-0.7398	-2.1056	**	-0.3588	-2.3353	**
Neighborhood amenity (including demographic interactions)						
MED_INC	0.3415	0.4143	n/s	0.0361	0.1199	n/s
EMP_DENS x LOW_INC	0.2814	0.5390	n/s	0.0477	0.2793	n/s
EMP_DENS x MID_INC	0.3161	2.0459	**	0.0956	1.5932	n/s
EMP_DENS x HIGH_INC	0.4564	3.7963	***	0.1435	2.2299	**
SCHOOL_DENS	1.2134	4.9360	***	0.4381	3.5228	***
Land attribute						
INDUSTRIAL	-0.1208	-4.3601	***	-0.0359	-2.7676	***
Upper nest						
Rail station within district						
TRAN_USER				0.4428	3.6890	***
HOME_RPASS				0.4713	2.9984	***
MEMBER_LESS_3				0.3489	3.0670	***
Dissimilarity						
Rail station within district (λ)				0.3518	4.9754	***
Rho-square (Nagelkerke)		0.2687			0.2874	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

Table 6 - 20 Residential Location Choice Model by Access to Each Line among Household Income (ROL and RONL model)

Variables	ROL			RONL		
	Parameter	t-Statistic		Parameter	t-Statistic	
Bottom nest						
Local transportation accessibility (including demographic interactions)						
DIST_GSTA x LOW_INC	-1.0355	-2.7280	***	-0.3064	-2.3350	**
DIST_GSTA x MID_INC	-0.9871	-8.3488	***	-0.2568	-4.6560	***
DIST_GSTA x HIGH_INC	-0.8534	-9.3466	***	-0.2111	-4.3945	***
DIST_BSTA x LOW_INC	-1.3689	-2.1508	**	-0.3300	-1.5570	n/s
DIST_BSTA x MID_INC	-0.5163	-2.1459	**	-0.0690	-0.9602	n/s
DIST_BSTA x HIGH_INC	-0.1032	-0.4794	n/s	0.0425	0.6904	n/s
DIST_ASTA x LOW_INC	0.3569	1.1260	n/s	0.1164	1.2340	n/s
DIST_ASTA x MID_INC	0.2405	2.4732	**	0.0267	0.9142	n/s
DIST_ASTA x HIGH_INC	0.1065	1.3974	n/s	-0.0122	-0.5253	n/s
DIST_RSTA x LOW_INC	1.8099	4.2427	***	0.5326	3.9213	***
DIST_RSTA x MID_INC	0.4967	4.0485	***	0.1186	2.9722	***
DIST_RSTA x HIGH_INC	0.3121	3.0573	***	0.0545	1.7419	*
DIST_PSTA x LOW_INC	-0.8232	-2.8840	***	-0.2477	-2.4118	**
DIST_PSTA x MID_INC	-0.2683	-3.3528	***	-0.0871	-2.8687	***
DIST_PSTA x HIGH_INC	-0.3005	-5.1877	***	-0.1005	-3.5235	***
DIST_EXP x NO_CAR	0.8648	6.2908	***	0.1705	3.0566	***
DIST_EXP x CAR_OWN	0.7831	6.2083	***	0.1274	2.5553	**
Work and non-work accessibility						
COM_TIME45m	0.1530	2.4767	**	0.0453	2.4864	**
Housing affordability						
LAND_PRICE	-1.2695	-5.1021	***	-0.4153	-4.1569	***
Neighborhood amenity (including demographic interactions)						
MED_INC	0.1143	0.2371	n/s	0.1766	0.9465	n/s
EMP_DENS x LOW_INC	0.4746	1.3919	n/s	0.1197	1.3893	n/s
EMP_DENS x MID_INC	0.2872	2.7840	***	0.0693	2.3112	**
EMP_DENS x HIGH_INC	0.2091	2.6479	***	0.0572	2.3700	**
SCHOOL_DENS	0.8623	4.8580	***	0.2851	4.6111	***
Land attribute						
INDUSTRIAL	-0.0944	-5.3952	***	-0.0212	-3.7762	***
Upper nest						
Rail station within district						
TRAN_USER				0.4563	4.2895	***
HOME_RPASS				0.3132	3.8334	***
MEMBER_LESS_3				0.1433	1.8633	*
Dissimilarity						
Rail station within district (λ)				0.3042	7.9709	***
Rho-square (Nagelkerke)		0.3036			0.3318	

*** = significant at 1% level

** = significant at 5% level

* = significant at 10% level

n/s = no significant

6.9.1 Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line

From Table 6 - 15 and Table 6 - 16, it can plot the coefficient effects of distance to nearest station of each line, namely BTS Skytrain (DIST_GSTA), MRT Blue Line (DIST_BSTA), Airport Rail Link (DIST_ASTA), SRT Red Line (DIST_RSTA) and MRT Purple Line (DIST_PSTA) as presented in Figure 6 - 6.

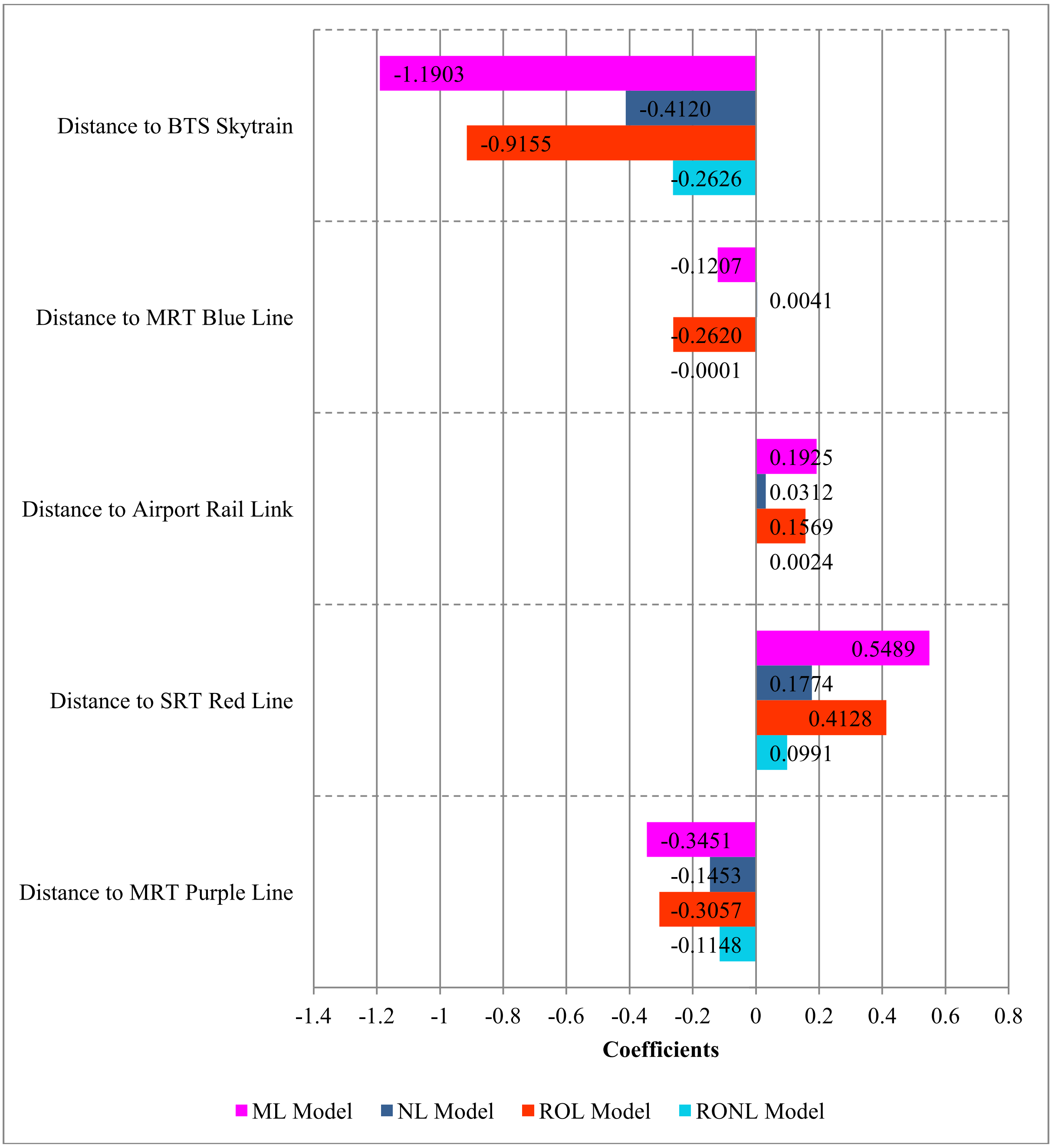

Figure 6 - 6 Coefficient Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line

In Figure, there are negative effects of the accessibility BTS Skytrain, MRT Blue Line and MRT Purple Line on residential location decision, but it found positive impacts on Airport Rail Link and SRT Red Line. These results indicate that households whose work office in the city center of Bangkok tend to live near BTS Skytrain, MRT Blue Line and MRT Purple Line. Notably, the effect of the accessibility to BTS Skytrain has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Blue Line and MRT Purple Line. This might be, first, BTS Skytrain and MRT Blue Line network serves households from outside areas directly into the CBD with the lower travel time. On the other hand, both Airport Rail Link and SRT Red Line network has to transfer to BTS Skytrain or MRT Blue Line network (need to pay fee again) before arrive to their workplace. However, even if the households who live near MRT Purple Line have to transit to MRT Blue Line but they pay the fee only one time.

Clearly, BTS Skytrain provides natural amenities to attract the choices of residential location than MRT Blue Line and MRT Purple Line, while Airport Rail Link and SRT Red Line conferred narrowly localized benefit in the location choices of residential.

6.9.2 Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line among Travel Mode Choices

Figure 6 - 7 plots the coefficient effects of distance to nearest station of each line, namely BTS Skytrain (DIST_GSTA), MRT Blue Line (DIST_BSTA), Airport Rail Link (DIST_ASTA), SRT Red Line (DIST_RSTA) and MRT Purple Line (DIST_PSTA) among travel mode choices (PRI_USER, PUB_USER and TRAN_USER) by the ML, NL, ROL and the RONL model from the Table 6 - 17 and Table 6 - 18.

In Figure, the results among travel mode choices present the similar trend as in Figure 6 - 7. In addition, there are negative effects of the accessibility to BTS Skytrain, MRT Blue Line and Purple Line on residential location decisions, but it still found positive impacts on Airport Rail Link and Red Line. Notably, the effect of the accessibility to BTS Skytrain has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Blue Line and Purple Line.

More specifically, when controlling for neighborhood attributes, private car users are more likely to live at locations which are close to the stations of BTS Skytrain and MRT Purple Line but less likely to live near the MRT Blue Line and SRT Red Line.

Among public transport users, their preferences and tastes with regard to residential location choice is quite similar to those private car users. They tend to locate close to the stations of BTS Skytrain and MRT Purple Line but still less likely to reside near the stations of MRT Blue Line.

On the other hand, urban rail transit users prefer to live close to the stations of BTS Skytrain as private car and public transport users, followed by the areas near the stations of MRT Blue Line and MRT Purple Line. However, the result shows the significantly positive impact of the accessibility to SRT Red Line.

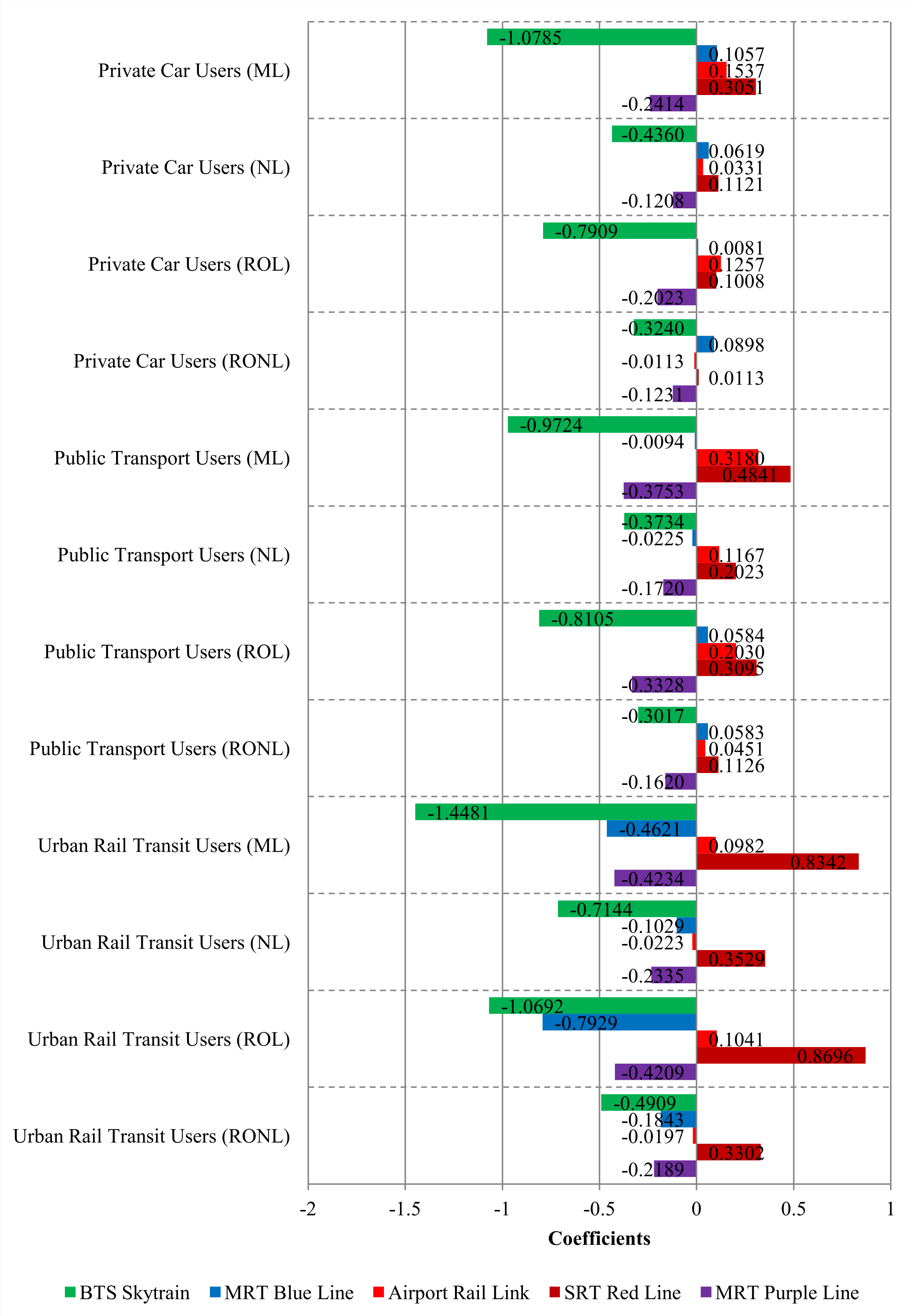

Figure 6 - 7 Coefficient Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line among Travel Mode Choices

6.9.3 Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line among Household Income

Figure 6 - 8 plots the coefficients of distance to nearest station of each line, namely BTS Skytrain (DIST_GSTA), MRT Blue Line (DIST_BSTA), Airport Rail Link (DIST_ASTA), SRT Red Line (DIST_RSTA) and MRT Purple Line (DIST_PSTA) among household income (LOW_INC, MID_INC and HIGH_INC) by the ML, NL, ROL and the RONL model from the Table 6 - 19 and Table 6 - 20.

In Figure, there are negative effects of the accessibility to BTS Skytrain, MRT Blue Line and Purple Line on residential location decisions, but it found positive impacts on Airport Rail Link and Red Line. Notably, the effect of the accessibility to BTS Skytrain has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Blue Line and Purple Line. Clearly, BTS Skytrain provides natural amenities to attract the choices of residential location than MRT Blue Line and Purple Line, while Airport Rail Link and Red Line conferred narrowly localized benefit in the location choices of residential.

More specifically, when controlling for neighborhood attributes, low income households are more likely to live at locations which are close to the station of MRT Blue Line, followed by BTS Skytrain and Purple Line.

Among middle income households, their preferences and tastes with regard to residential location choice differ from those of low income households. Middle income households tend to locate close to the stations of BTS Skytrain. This is followed by the chance to residing near the stations of MRT Blue Line and MRT Purple Line.

On the other hand, high income households prefer to live close to the stations of BTS Skytrain as middle income households but followed by the areas near the stations of MRT Purple Line and MRT Blue Line.

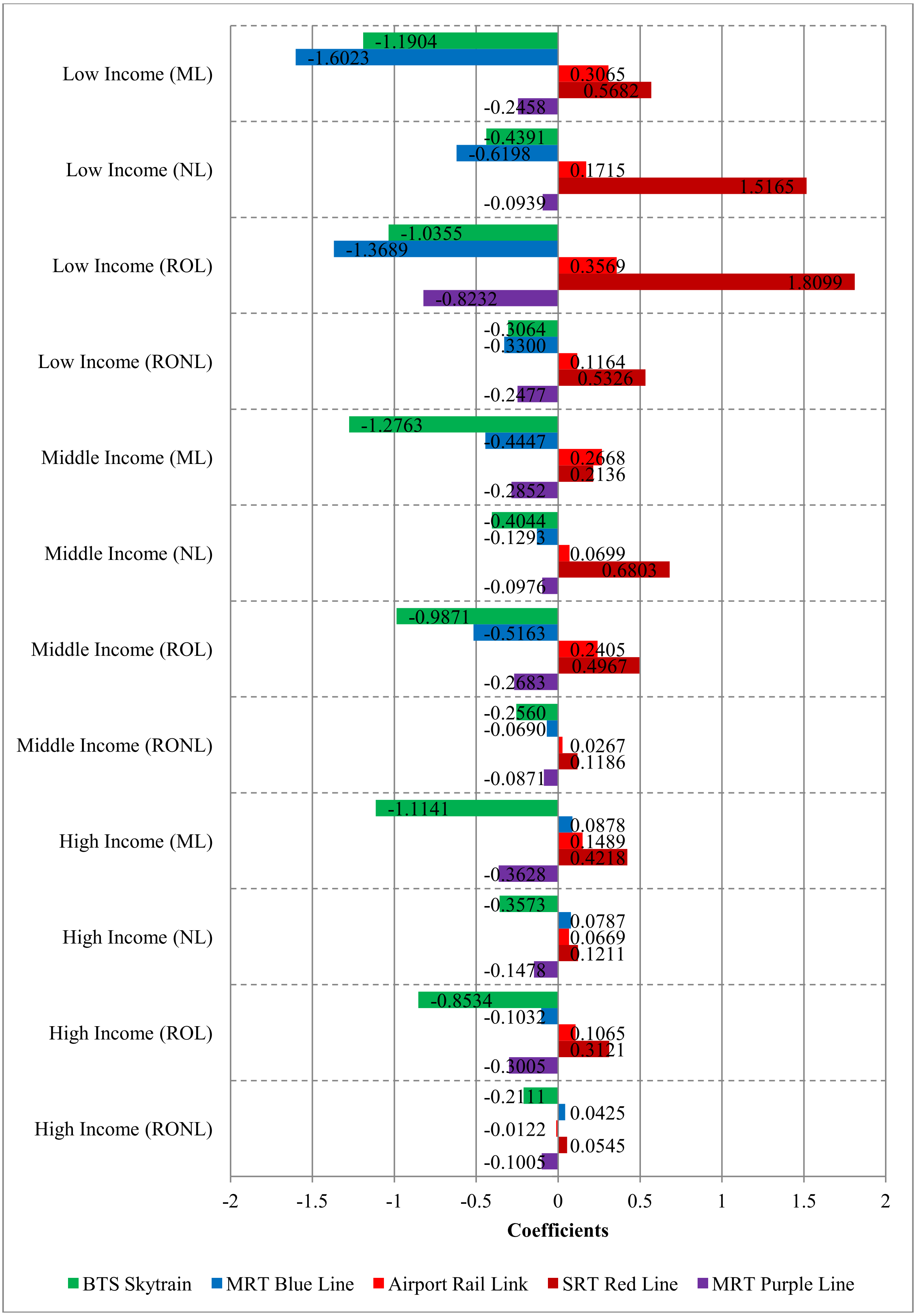

Figure 6 - 8 Coefficients Coefficient Effects of Urban Rail Transit Investment on Residential Location Decision by Access to Each Line among Household Income

6.10 Summary

This chapter is to determine whether the effect of urban rail transit improvement associated with residential location decision behavior. Residential location decision data obtained from paper-based questionnaire survey. In this chapter, three existing urban rail transit including BTS Skytrain, MRT Blue Line, Airport Rail Link, and two under construction line including SRT Red Line and MRT Purple Line were used to capture the effects of urban rail transit policies on the residential location decision behavior of workers in the central business district (CBD) of Bangkok Metropolitan Region where the largely concentration of employment is located. It is, furthermore, all of urban rail transit lines are the policy to solve the congestion on main road head to the CBD area.

First, this chapter develops a methodological framework for the analysis of residential location decision behavior. An application of discrete choice model, namely multinomial logit (ML) is widely used in many previous literatures due to its flexible and easy interpretation. However, the current study is developed logit framework for ranking experiment, i.e., the extension of the ML model namely rank-ordered logit (ROL) model. Ranking data provides more statistical information than choice experiments, which lead to tighter confidence intervals around the parameter estimates (Malaitham *et al.*, 2013; Merino-Castello, 2003). The ROL model has been known and used for measuring consumer preferences for a long time, but so far has rarely been explored and employed for the context of analyzing location choices. Furthermore, the two-tiered rank-ordered nested logit (RONL) is an alternative to relax assumption of the ROL model namely the independence of irrelevant alternative (IIA), i.e., the development of a nested logit (NL) framework for ranking data. Thus, multinomial logit (ML), nested logit (NL), rank-ordered logit (ROL) and rank-ordered nested logit (RONL) were applied to treat the behavioral interpretations of residential location. In addition, the NL, ROL, and RONL were estimated by referring to an ML model.

Among all of the four models, it can be seen that the RONL model is much consistent with the obtained data compared with the other models and is then followed by the ROL model, indicated by rho-square (ρ^2), i.e., the results show that the model fit improves as the model complexity increases.. In addition, if I compare the estimated results obtained from using the ROL model with the results derived from the RONL model, the RONL model is still much consistent with the obtained data than the ROL model which suggests that grouping subsets of alternatives that are more similar to each other with respect to excluded characteristics than they are to other alternatives can offer great benefits (Malaitham *et al.*, 2013). Furthermore, the model fit also confirms that ranking of alternatives provides more statistical information than chosen alternative even if both of them (e.g. the ROL model compared to the ML model) follow the assumption of the independence of irrelevant alternatives (IIA) while the NL model and the RONL model partially relax it. This implies that the application of the discrete choice model for ranking of alternatives can be feasibly estimated and is useful in applied or future work of residential location choice decisions. Another important element of this study is the dissimilarity of parameters. The results found that these parameters are statistically significantly smaller than one indicates which strongly supports the hierarchical nest structure.

Next, one of the main objective aims to investigate the influencing factors impact on the residential location choice behavior using discrete choice frameworks as explained above. The important findings from the empirical analysis are as follows. First, local transportation accessibility does affect residential location decisions. For example, the models confirm the influencing of the proximity to rail transit station, i.e., the closer to them, the preferable to choose. Moreover, among travel behaviors, mainly get around by rail transit, is a key variable in affecting the sensitivity to the urban rail transit service availability. Furthermore, while the proximity to transit stations is generally recognized as the dominating factor in rail transit user group, car ownership likely influences the decision to live closer to expressway access. These imply that travel behavior and socio-demographics (i.e. car ownership) are the dominant factor in residential sorting. In contrast, residential location decision impacts on the travel behavior and car ownership decisions as well. Thus, policy decisions regarding changes in local transportation accessibility and neighborhood attributes have to be evaluated in the context of these decisions. Moreover, this information is important suggesting appropriate policies that promote transit use such as transit-oriented development, i.e., improving station area to more effectively and provide feeder modes with cost effective and high security and safety. Next, another socio-demographic, i.e., household income is the determinant factor of segregation phenomenon in choice of residential location. Other demographic factors that impact residential preferences correspond to the size of household, such that single or couple households tend to draw themselves near the rail transit stations. Besides, households prefer to live in the same neighborhood in which they lived before.

Another objective of this chapter is to investigate the effects of urban rail transit on residential location decision. The residential location choice model indicated that the effect of the accessibility to BTS Skytrain stations has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Purple Line and MRT Blue Line stations, i.e., households prefer living near the BTS Skytrain stations, followed by MRT Purple Line and MRT Blue Line stations. Among travel mode choices, private car users are more likely to choose the locations near BTS Skytrain but less likely to reside closer to SRT Red Line. Furthermore, among urban rail transit users, they prefer to live close to the stations of BTS Skytrain, followed by the areas near the stations of MRT Blue Line due to the fact that areas can access the station easily with various feeder modes. Besides when controlling for neighborhood attributes, low income households are more likely to live at locations which are closer to the station of MRT Blue Line but high income households prefer to live close to the station of BTS Skytrain as middle income households. Notably, low income households are less likely to reside along the adjacent area of SRT Red Line.

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CHAPTER 7

CONCLUSION

The main purpose of this dissertation is to evaluate the effects of urban rail transit development in Bangkok Metropolitan Region. Up until this chapter, three principal ways regarding to land use change, land value and residential location decision were examined in study areas located along urban rail transit network: BTS Skytrain, MRT Blue Line, Airport Rail Link, SRT Red Line and MRT Purple Line. This chapter concludes the findings obtained from the examination in chapter 4 to chapter 6. Next, the limitations in this study were summarized. Further, the study contribution and implication are explained. Finally, the future prospects for further research regarding this filed are discussed.

7.1 Summary of Findings

As mentioned, that urban rail transit brings large effects to the relative attractiveness of the locations near the railway networks is well recognized in many developed countries, however, in a city being young in urban railway experience is not gaining more attention. This research attempts to understand the effects of urban rail transit network expansions on land development: land use change, land value and residential location in Bangkok Metropolitan Region. The benefits due to rail transit development also impact on the areas which are announced in the top priority project in 20 years plan extension. However, lacking an idea to corporate land development impact into planning and evaluation of a transport project causes difficulty to accurately estimate its impact and benefits. Therefore, it is necessary that planning and evaluation of transport project need to be improved. The information from the studies is able to describe and to identify the extent of land development impact consideration in the planning and evaluation process.

The econometric models confirm that the urban rail transit development have changed the land development in terms of land use change, land value and residential location choice. The results from the models vary with socioeconomic and locational attributes such as local transportation accessibility, work and non-work accessibility, neighborhood amenity and land attribute. The urban rail transit development resulted in higher land price and an invisible increase of land development among residential, high-rise residential and non-residential property as well as a higher agglomeration of population and household near the urban rail transit corridors. For instance, BTS Skytrain and MRT Blue Line network connected to the central business district (CBD) of Bangkok Metropolitan Region generated high-rise residential developments (e.g. luxury condominium and apartment) with higher values near their stations which correspond to the empirical evidence in the previous literature (Vichiensan *et al.*, 2011), residential development was greatly found that in the area along the Airport Rail Link corridor with the lower value than those development in adjacent area of BTS Skytrain and MRT Blue Line corridor. Further, those urban rail transit lines induce the conversion urban from to non-residential properties (e.g. office building, shop store, etc.) with higher bid-rents as suggested in Chalermpong and Wattana (2010), but this effect was not found within 3 kilometer of the Airport Rail Link. Moreover, the estimated premium for urban rail transit accessibility is approximately 15 percent for residential land and non-residential land price along the BTS Skytrain as well as 10 percent for residential land and non-residential land price along the MRT Blue Line which relatively high, but still within a reasonable range as found in the past results in other developing countries (Bae *et al.*, 2003; So *et al.*, 1997). However, the capitalization effects of proximity to Airport Rail Link stations found that the beneficial effects will worth less than 4 percent to residential land parcels and 2.5 percent to non-residential land parcels along the Airport Rail Link corridor. Besides, the residential location choice model indicated that the effect of the accessibility to BTS Skytrain stations has a remarkably high influence on residential location decisions compared with the effects of accessibility to MRT Purple Line and MRT Blue Line stations, i.e., households prefer living near the BTS Skytrain stations, followed by MRT Purple Line and MRT Blue Line stations but less likely to live near the Airport Rail Link and SRT Red Line corridor. Among urban rail transit users, they prefer to live close to the stations of BTS Skytrain, followed by the areas near the stations of MRT Blue Line due to the fact that areas can access the station easily with various feeder modes. Likewise, private car users and public transport users also prefer to live near BTS Skytrain stations. When controlling for neighborhood attributes, low income households are more likely to live at locations which are close to the station of MRT Blue Line but high income households prefer to live close to the station of BTS Skytrain as middle income households. Notably, low income households are less likely to reside along the adjacent area of the SRT Red Line.

In accordance with the explanations, they are notable that land development is a sequential process as a result of urban rail transit development. After BTS Skytrain and MRT Blue Line started their service, land along the corridors tended to be converted to residential uses uses where households were more likely to reside that is the reason for the land value uplift due to the extremely competition among the sites. On the other hand, households are less likely to prefer living in this zone along the Airport Rail Link corridor, however, the results also found in the same direction but lower value than BTS Skytrain and MRT Blue Line. This is considered as benefit brought by the urban rail transit development.

7.2 Policy Implication

According to the obtained results, policy makers should consider and evaluate the effects of urban rail transit into the transportation project. The results of this dissertation raise some policy implications in order to maximize potential opportunities to make sustainable for the local services and allow the government to finance infrastructure projects by selling land in the affected districts in advance as follows.

First, this has implication in determining the future land development as a result of the urban rail transit development. On the other word, the study is able to calibrate the new development which can provide helpful insight into the future land patterns. As known, urban rail transit development brought a huge impact on land development especially in outer city areas. The rapid growth has led challenges including how to get around, access to neighborhood services, school and shopping center, etc. Thus, prediction of land use change provides critical information for making the right policies and management plans in order to maintain and improve public good and services. For example, policy maker should consider the appropriate policies concerned with the control of the use of land and design or re-design the landscape and built environment including dense setting and convenient, safe, punctuality and adequate local transportation system to other areas. These plans provide a political support and create a greater impression on local people.

Second, this has implication in determining the beneficial drawback in term of property tax, which must be higher for the area being well serviced by urban rail transit network. Increase in land value premiums generated by the urban rail transit development conferred unintentional benefits to land owners. Although opportunities to finance urban rail transit infrastructure through value capture policies have long recognized, such policies have not been implemented in Bangkok Metropolitan Region's transportation planning projects due to lacking of understanding of the capitalization, particularly, the lack of concrete evidence of how urban rail transit accessibility development influence value uplift. One of the chapters in this dissertation provides evidence to measure the localized benefits through the land price model which gives us an opportunity to design value for retuning the direct beneficiaries of land value uplift to the public sector. The beneficial draw back would be used to expand other transportation projects and provide more service that related to urban rail transit.

Third, the location choice models of residential confirm that the urban rail transit development provides the favorable urban setting to attract household to reside. The public policy should focus on expanding urban amenities and providing convenient public transport service. Furthermore, the goal of implementation of urban rail transit is to solve the critical traffic congestion. However, households prefer to live near the urban rail transit corridors, it is not guarantee whether they will use the urban rail transit or not. Policy makers should consider the appropriate policies that promoting urban rail transit use such as transit-oriented development (TOD).

7.3 Limitations

The research has attempted to understand whether the land development in terms of land use changed, land value and residential relocation decision is associated with the effects of urban rail transit implemented in particular those areas. The study focused mainly on the existing urban rail transit network and now under construction in Bangkok Metropolitan Area and its vicinities which mainly consist of Nonthaburi Province, Prathum Thani Province and some part of Sumuth Prakarn Province.

Since this research is an empirical study, it is necessary to collect several data from various sources. However, in this study have some limitations. First, the land use changed data was obtained from the satellite image processing. However, Bangkok Metropolitan Region has implemented the urban rail transit since December1999. Thus, only two years of land use data were employed to observe the conversions of land use along the urban rail transit corridors around 5 kilometer radius from each station.

Second, the information on land value was obtained from the four-year-period assessed land value report which was published by Treasury Department during the year 2008 and 2011. Typically, assessed value (price) is the value used by local governments to determine the property taxes. This is generally an unrealistic value, i.e., market value. Although the appraised land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand.

Finally, for the residential location decision, the questionnaire was developed using a stated-preference (SP) method to reflect the individual's preference behavior whether the existence of transport facilities especially rail transit system related to residential location decisions because the revealed data for residential location choice is unavailability for publication.

7.4 Further Research

This dissertation has reviewed several literatures, both academic and practical oriented; both international and local perspective, regarding the influencing of urban rail transit development. It has come up with some indicators that used to identify the effects of the existing urban rail transit lines and even under construction network in Bangkok Metropolitan Region. The case study has shown that urban rail transit plays important role in urban structure development and reform which leads a premium value and attract households to reside in the adjacent areas. An investigation in this dissertation provides insight on the remaining, lacking and challenging research themes that essential and substantial to be conducted in Bangkok Metropolitan Region in terms of urban and transportation planning.

First, according to the limitations, land use change models established from one states: undeveloped land. However, in the real situation, it challenges to consider other types of land use such as residential uses to high-rise residential uses, to non-residential uses, from high-rise residential uses to non-residential uses and etc. Further research theme is to understand the processes of land use change effects of urban rail transit development in term of duration model. A limitation of the discrete choice framework is lack of temporal dynamics that enter the model (Plantinga and Irwin, 2006). For example, the more interesting question may not be whether a parcel is converted, but rather when a parcel is converted. Duration model explicitly account or the timing of qualitative change from on state to another and therefore are and appropriate way to capture the cumulative effects of urban rail transit on the transition probability.

Second, as mentioned in the implication, the idea, known as "value capture" is a type of public financing that recovers some or all of the value that public infrastructure generates for private property owners. In order to successful, the strategies of value capture in recent literatures include as follow: joint development, negotiated exactions, special assessment districts, development bonus, air rights, tax increment financing, development impact fees, transportation utility fees and land value tax (Mathur, 2005). One of the interesting is which strategies appropriate the local government or public sector to harness the value created through urban rail transit infrastructure improvement in each area and to use these funds to pay such improvements. Then, further research is how to make suitable conditions and provide legal, administrative and technical recommendations for using these funding in urban rail transportation finance. Finally, another theme is how to evaluate the applicability of value capture in funding urban rail transit expanding.

Third, in this dissertation, the adjacent areas of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become the attractiveness areas for land development, e.g., residential and commercial development. With high demand for sites that offer good rail transit opportunities, it is in turn lead to increased land price as competition. Meanwhile, in the opposite direction, one of the interesting but less investigated topics is how urban rail transit development affects the change of land value that leads to land use conversion. The future study will confirm the dynamic response of land value to urban rail transit development.

Forth, land price data in this study obtained from the assessed land value report which was published by Treasury Department, Thailand as explained. This kind of data is not the real market value, i.e., appraised value which is the valuation of a piece of real estate for the purpose of determining the amount of property taxes owed on that property. In fact, the appraised value of land does not always keep up with the real market value. Specifically, appraised values are based on gathered data and the local government conducts the appraisal, while the market value has more variance than the appraised value. However, market transaction value data is not consistent, reliable and unavailability in the past. Therefore, it challenges to collect the present market value and applies them to examine in the same theme in order to identify the difference between the capitalization effects of the urban rail transit development on the appraised value and market value. Finally, this data can be applied to forecasting land price model of the capitalization effects of the urban rail transit development in the future.

Fifth, there is a great need for a better understanding of the complex interactions between residential location and other aspects such as middle term (e.g. car ownership) and long term (e.g. work location) decisions. Further, according to the implication, the idea, known as "transit-oriented development (TOD)" is an approach to development that focuses land uses around an urban rail transit station or within corridors. Typically, it is characterized by: a mix of uses, moderate to high density, pedestrian orientation/connectivity, transportation choices, reduced parking and high quality design. One of the interesting themes is to identify the current situation of TOD at each existing station. Then, further research is how to design standards or guidelines of TOD for Bangkok Metropolitan Region that new development of redevelopment of existing sites is pedestrian-friendly, attractive and connects the neighborhood to the urban rail transit station. Next, it is also necessary to evaluate the successful of TOD implemented in the given areas. However, TOD occurs within one-quarter mile or a five to seven minute walk of station. Thus, it challenges to study an existing feeder potential and suggests the plans to improve the service quality and finally, is to promote all of these aspects into the urban and transportation planning development.

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